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SCIENCE PROGRESS

THE CAPE OBSERVATORY AND ITS WORK

By H. SPENCER JONES, M.A., Sc.D., F.R.S., Astronomer Royal

The first proposal to establish an Observatory at the Cape of Good Hope was made at a meeting of the Board of Longitude, on February 3, 1820, with Viscount Melville, First Lord of the Admiralty, in the Chair. At that meeting, according to the minutes of the Board, "Mr. Gilbert proposed that the Board should take into consideration the propriety of the establishment of an observatory at the Cape of Good Hope, which he observed was likely to be highly conducive to the improvement of astronomy. The motion was seconded by Sir Joseph Banks,[1] who gave it as his opinion that nothing could more essentially promote the glory of this country than to be foremost in such an undertaking." As a result of this minute, enquiries were set on foot as to the cost of providing suitable instruments. On October 9, 1820, the Secretary of the Colonial Office addressed a letter to the Secretary of the Admiralty stating that Earl Bathurst, the Colonial Secretary, had instructed the Governor of the Cape to allot a suitable piece of ground for the purpose of the erection of the Observatory, at the expense of the Colonial Government, and in such a situation as the Astronomer, whom the Lords of the Admiralty might send out, would think fit and eligible and, moreover, to lend every possible assistance towards carrying into effect the object in view. The Observatory was finally established by Order in Council, dated October 20, 1820. The staff was to consist of one astronomer, one assistant and one labourer, and the Rev. Fearon Fallows, Fellow of St. John's College, Cambridge, was appointed as the first of His Majesty's Astronomers at the Cape. By the instructions given to Fallows, he was to make observations "as much as possible of the same kind and in the same manner as the Greenwich observations have been usually made."

[1] President of the Royal Society, 1778–1820.

Fallows sailed for the Cape on May 4, 1821, in the *Sappho*, and arrived at Cape Town on August 12. His first concern was the selection of a suitable site for the Observatory. The choice was limited by the conditions that the site had to be on Government property, within sight of Table Bay so that time-signals could be given to vessels in the anchorage, and as far as possible free from sandy dust. Fallows finally selected the present site of the Observatory, between the Liesbeek and Black Rivers, on the foot-slopes of Devil's Peak. It was none too promising a spot, being a low, bare rocky hill, infested with snakes and covered with thistles, jackals howled round it at night and a guard of soldiers had to be provided as a protection from theft. There were no roads and no water-supply; in the winter, it was exposed to the full force of the north-west gales and in the summer to the strong and gusty south-east winds. The present Observatory, on the site selected by Fallows, now well protected from the strong winds by trees, is shown in the Frontispiece, which is reproduced from a recent pencil drawing by the South African artist, Mr. Charles Peers. The Main Building of the present Observatory (carrying the flagstaff) comprised the whole Observatory in the time of Fallows. Fallows had innumerable difficulties to contend with: delay in commencing the buildings, lack of support from a parsimonious government and unsuitable and inefficient local labour. Even when the Observatory had been built and the instruments installed, he had serious difficulties with the mural circle, which had excessively large division errors and a deformed pivot. His efforts to improve the site were not viewed sympathetically by the Admiralty. In response to his request for a small grant for planting trees to break the force of the persistent winds, he was informed that, if he had any desire to beautify the grounds, it must be done at his own expense. In the new colony, education of children was not an easy matter. Fallows opened a school and in his spare time he gave lessons to the children of the neighbouring farmers, taking a load of earth as a fee for each lesson; in this way a covering of soil for a portion of the bare stony ground was provided. Amidst these difficulties, Fallows applied himself with zeal to the observation of the Sun, planets and southern stars. But he was handicapped by difficulties with his small staff, general sickness in the establishment and delays in filling vacancies; if it had not been for the assistance of Mrs. Fallows, the output of observations would not have been so large as it was. Fallows' constitution, weakened by an attack of scarlet fever in 1830, and undermined by the anxieties and worries which beset him, proved unequal to the

task and he died in 1831 at the age of 42 years. His observations were taken to England by his wife and were reduced and prepared for publication by Sir George Airy, Astronomer Royal.

Thomas Henderson, who was appointed to succeed Fallows, was a Scotsman of 34 years of age, who had already acquired a considerable reputation as an astronomer. During the brief period, barely exceeding one year, that he remained at the Cape, astronomical observations were energetically pursued. The output in this brief period was surprising. It included observations of position of over 5,000 stars, observations of the Moon which gave the most accurate value of the Moon's parallax then available, observations of Mars and adjacent stars for the determination of the distance of the Sun, and also observations of occultations of stars, of eclipses of Jupiter's satellites and of comets The longitude of the observatory was determined and modern methods have closely confirmed Henderson's value. But Henderson will always be remembered principally for his determination of the distance of the star α Centauri. The observations of α Centauri were not made primarily for the purpose of determining the parallax, but during the discussion of the observations, both in right ascension and in declination, it became apparent that the star had a large parallax. The results of the determination were communicated by Henderson to the Royal Astronomical Society in 1839, about the same time that the determinations of the parallax of α Lyrae by Struve and of 61 Cygni, by Bessel, were published. Thus the problem of determining the parallax of a fixed star was solved for the first time and practically simultaneously by three astronomers, observing three different stars. α Centauri still remains the nearest known star, with the exception of a faint component, physically connected with it, which appears to be slightly nearer.

Henderson was not, physically, a strong man and his health soon began to be impaired. He was not prepared to fight a long battle against official parsimony, procrastination and neglect. He resigned his post and returned to Scotland, being shortly afterwards appointed Astronomer Royal for Scotland. He prepared a detailed memorandum on the condition of the Cape Observatory, in which he forcibly set down the difficulties which had to be contended against. Referring to the position of the Observatory he states that: "Its situation upon the verge of an extensive sandy desert, exposed to the utmost violence of the gales which frequently blow, without the least protection from trees or other objects to shelter from the wind or sun, some miles distant from markets, shops or the inhabitations of persons with whom those belonging to the

Observatory can associate, the want of good water, and the state of the bulk of the population from whom servants must be taken and other aid applied for, will always prove considerable drawbacks from the comforts of persons sent from England to do the duties of the Observatory, and great obstructions to the undisturbed cultivation of the Science."

Henderson was succeeded at the Cape by Thomas Maclear. He was an Irishman, born in 1794, who had adopted a medical career, with astronomy as a hobby, which he pursued in the times which he could spare from his professional duties. He had been house-surgeon of the Bedford Infirmary and was in private practice at Biggleswade, when he was appointed H.M. Astronomer at the Cape. He arrived there at the beginning of 1834, and was destined to remain in charge of the Observatory until his retirement in 1870, to ameliorate the conditions of life there and to make it an active centre of scientific work in the Colony

Ten days after Maclear reached the Cape, Sir John Herschel arrived with his family and instruments. These were erected on a site which Herschel purchased at Feldhausen, Claremont, a few miles from the Cape Observatory. The purpose of Herschel's visit was to make a survey of the southern sky along lines similar to that which his father, Sir William Herschel, had made of the northern sky. The visit extended over four years; Herschel's observations included the cataloguing of nebulæ, star clusters and double stars; star-gauging, counting the number of stars to different degrees of magnitude seen in the field of the telescope in different parts of the sky—for the purpose of determining the distribution of the stars in space; surveys of the Magellanic clouds; observations of Halley's comet, of double stars, of the principal nebulæ, star clusters, etc. It was a fruitful time for astronomy and a great stimulus to Maclear in his early years at the Cape.

Maclear set to work with untiring energy to improve the site, by planting trees, carting earth, improving the water-supply, providing necessary outbuildings, etc. He was undaunted by official neglect and persisted in his demands until he had made the Observatory a place in which it was possible to live with reasonable comfort. At the same time, astronomical observations were vigorously pursued, as many as 10,000 star transits being observed in a single year. The result of this intensive observing on the part of the small staff of the Observatory was that observations were accumulated at a rate very greatly in excess of that at which they could be reduced. No provision had in fact been made by the Admiralty for the routine work of computation. Fallows'

observations had been reduced at Greenwich after his death; Henderson had reduced his own observations at Edinburgh after his retirement from the Cape. Maclear was, in his later years at the Cape, worried by demands for the early publication of results, with which he could not comply except by stopping observing. That he was wise in deciding not to do so, in view of the little knowledge available as to the positions and movements of the southern stars, there is little doubt. His observations were reduced subsequently and are invaluable for the purposes of fundamental astronomy in the Southern Hemisphere.

An important task which Maclear undertook, in addition to his other duties, was the verification of the arc of the meridian which had been measured by the Abbé de Lacaille. The Abbé had gone to South Africa in 1751 to make a survey of the stars in the southern skies. Whilst engaged on this work, he realised that it would be possible without great difficulty to measure an arc of the meridian northwards from Cape Town. It was not known at that time whether the form of the Earth in the Southern Hemisphere was similar to its form in the northern. An investigation of this question was of some interest to Lacaille in connection with the reduction of observations on which he was then engaged for the determination of the parallax of the Moon. Lacaille's observations to determine the length of a degree of latitude were made in the year 1752. The length of the degree was found to be greater than would be expected, if the form of the Earth was the same in the northern as in the southern hemispheres. For nearly a century the reason for this discordance remained unexplained Between the years 1840 and 1842, Maclear connected Lacaille's points of observation by a triangulation which was extended both to north and south of Lacaille's terminal points. It is of interest to note that on the summit of Riebeek Casteel, Maclear found the undisturbed charcoal remnants of Lacaille's beacon fire of 1751; these are now preserved as an interesting historical relic at the Cape Observatory. Maclear's observations proved satisfactorily that the form of the Earth is closely the same in the two hemispheres, and showed that the apparent error in Lacaille's survey was due to a large local disturbance, amounting to more than 8 seconds of arc, of the direction of gravity at his northern station.

Sir Thomas Maclear resigned his post in 1870 and was succeeded by E. J. Stone, who for the previous ten years had been Chief Assistant at the Greenwich Observatory. Stone was sent to the Cape with explicit instructions to undertake the reductions of Maclear's numerous meridian observations and to make them avail-

able to astronomers with as little delay as possible. During the nine years that Stone was at the Cape, until his return to England as Radcliffe Observer at the Radcliffe Observatory, these reductions were energetically carried on; the work was completed by Gill after his appointment as successor to Stone. The results were published in the form of several star catalogues. But Stone did not limit himself to the reduction of his predecessor's observations. Meridian observations were energetically continued, with a view to the formation of a general catalogue of southern stars to about the 7th magnitude, the reductions of these observations being kept vigorously up to date. Stone left for Oxford when the observations were finished, and there completed his great catalogue, which was published in 1881 as the *Cape Catalogue of 12,441 Stars for the Equinox 1880*. Gill wrote of Stone that "but for the simultaneous and almost phenomenal labours of Gould at Cordoba it might be said of Stone that he created our knowledge of the exact sidereal astronomy of the Southern Hemisphere."

Stone's successor at the Cape was David Gill, who since 1872 had been in charge of the private observatory of Lord Lindsay (afterwards the Earl of Crawford) at Dun Echt. Gill had already made his mark in the astronomical world, particularly by his expedition to Ascension in 1877, to make heliometer observations of Mars at its favourable opposition in that year, for the determination of the solar parallax. One outcome of this investigation was the discovery that there was a systematic personality, depending upon the star's magnitude, in meridian determinations of right ascension (the so-called "magnitude equation"). With Gill's appointment a new epoch opened in the history of the Cape Observatory. Hitherto, observations had practically been confined to that branch of astronomy which is termed fundamental astronomy, the determination of positions of Sun, planets, stars, etc., and of their motions. Under Gill, the work of the Observatory developed in various directions and additions were made to the instrumental equipment. Within the compass of a brief article, it is not possible to deal with all the new developments; it must suffice to refer to just a few of them.

One of the most important developments, both for the Cape Observatory in particular and for astronomy in general was the application of photography to astronomy. In September 1882 a bright comet was discovered by W. H. Finlay, then First Assistant of the Cape Observatory. It occurred to Gill that it would be of interest to photograph the comet with a camera strapped to an equatorial telescope, so that the diurnal motion could be counter-

acted. The Observatory possessed at that time no photographic lens and no member of the staff was experienced in dealing with the modern dry plate. Gill therefore called upon a local photographer for help and several photographs were obtained, for some of which the telescope was guided upon the nucleus of the comet and for others upon the stars. Some excellent photographs of the comet were obtained, but what impressed Gill most was that the photographs obtained when the telescope was guided upon the stars showed so many stars, well-defined over a large area. He at once realised the importance of photography for the construction of star-maps. The results were communicated to the Paris Academy of Sciences and an immediate outcome was that the brothers Henry were encouraged by Admiral Mouchez to devote their attention to the design and construction of lenses suitable for astronomical photography.

The first result of the new development was the collaboration of Gill and of J. C. Kapteyn, of the University of Gröningen, in the production of the Cape Photographic Durchmusterung. In preliminary correspondence on the subject, Kapteyn had written to Gill, "I think my enthusiasm for the matter will be equal to (say) six or seven years of such work." The plan was to determine the positions and magnitudes of all stars in the southern sky down to a magnitude limit of 9·0. The photographs were to be taken at the Cape with a 6-inch rapid rectilinear Dallmeyer lens, the measurement and reduction of the plates was to be undertaken by Kapteyn at Gröningen. This plan was not carried out in its entirety; Gill had relied upon support from the Royal Society, but when in 1887 the International Astrophotographic Congress resolved that a catalogue of stars to the 11th magnitude should be undertaken by international co-operation, the Royal Society took the view that Gill's Photographic Durchmusterung was no longer necessary. Gill realised, however, that the complete execution of this international plan would require a long interval of time (the work is even now not completed) and decided to carry on his plans on a modified scale, not continuing the work north of declination $-18°$ and measuring the plates to an accuracy of a tenth of a minute of arc only instead of to an accuracy of a second of arc, as originally proposed. To carry the plan through on this scale, Gill financed it largely from his own private resources. Kapteyn began the work of measurement in October 1886 and finished it in February 1898, thus devoting over eleven years to it, as compared with the six or seven which he had promised at the outset. The results were published in three large volumes, containing photographic

magnitudes and positions of 454,875 stars. The value of this publication to sidereal astronomy in the Southern Hemisphere cannot be overestimated.

Gill was also largely responsible for the inception of the international astrographic chart and catalogue. As mentioned above, the brothers Henry, at the suggestion of Admiral Mouchez, had turned their attention to the design of lenses suitable for astronomical photography. Some photographs which they obtained with lenses of their own design and construction were forwarded by Mouchez to Gill. Gill then suggested that the time had arrived when steps should be taken to map the whole sky on a uniform plan by international co-operative effort and that the best method of securing this would be to call an International Congress meeting at Paris. Shortly before the Congress met, Gill further suggested that the programme should be extended to include a catalogue as well as maps. The Congress met in April 1887 and it was resolved to chart the sky in duplicate (by overlapping plates) to stars of the 14th magnitude and to take a separate series of plates, with shorter exposure, for the purpose of forming a catalogue of all stars to the 11th magnitude. The sky was divided into zones of declination, which were assigned to different observatories. The largest share was taken by the Cape Observatory, with the zone from $-40°$ and $-52°$ declination, involving 1,632 areas, each $2° \times 2°$. The photographic objectives were to be of about 13 feet focus, giving a scale on the plate of 1 mm. = 1 minute of arc and an aperture of 13 inches.

The telescope was provided by the Admiralty and the photography of the Cape zones was commenced in 1892. The measurement of the photographs was completed after Sir David Gill's retirement in 1907 by his successor, Mr. S. S. Hough, who had been Chief Assistant to Sir David Gill since 1898. The publication of the results, in twelve large volumes, was completed shortly after Mr. Hough's death in 1923. After my appointment to the Cape in succession to Hough, the whole of the Cape zones were rephotographed and each new photograph measured differentially against the corresponding earlier photograph, with an average time-interval of twenty-five years, to determine the apparent angular motions (proper-motions) of the stars. The reductions of these measures are nearing completion and the result will be the determination of the proper-motions of some 40,000 stars—material of the greatest value for statistical purposes.

Mention has been made above that before Gill went to the Cape he had made an expedition to Ascension to make observations of

Mars with a heliometer for the determination of the solar parallax. The heliometer is an instrument in which the objective is cut into two halves which can be slid apart along their common diameter, the separation of the two halves being measured by divided scales. It is the most accurate visual instrument for the measurement of angular distances, up to about 2°, between different celestial bodies. It was a favourite instrument with Gill who, incidentally, was a remarkably skilled observer with it, probably the best heliometer observer there has ever been. Gill purchased from Lord Crawford his 4-inch heliometer and used it, with the assistance of Dr. Elkin, who came to the Cape for the purpose, for a period of eighteen months in 1883–84 to determine the parallaxes of nine southern stars. The results having substantiated the suitability and accuracy of the heliometer for such observations, Gill applied to the Admiralty for a 7-inch heliometer, which was approved and completed in 1887. This instrument was used for a larger series of parallax determinations, which materially contributed to the knowledge of the distances of the stars at that time. Gill's own observations gave results comparable in accuracy with the results given by modern photographic methods. His average probable error for a single observation with the heliometer was about 0″·06, a value never equalled, I believe, by any other observer. The instrument has been employed regularly for the last 36 years for determining the positions of the major planets. The 7-inch heliometer dome is shown in the Plate facing page 16.

When applying to the Admiralty for the new instrument Gill had foreshadowed its use for the determination of the solar parallax from the observation of suitable minor planets, when relatively near to the Earth at favourable oppositions. Minor planets are preferable to planets showing a disc, such as Mars, which Gill had observed at Ascension, because their images in the instrument are stellar in appearance. The accuracy of the observations is increased and systematic errors are to a large extent eliminated. At that time, the value of the solar parallax (or of the mean distance of the Sun from the Earth) was still very uncertain. The transits of Venus in 1874 and 1882, from which so much had been expected and for whose observations many costly expeditions had been sent out, had proved unsuitable for the purpose. It was found impossible to determine with any accuracy the instants of contact of the limbs of Venus with the limb of the Sun. The minor planets which Gill planned to observe near opposition were Iris in 1888, Victoria and Sappho in 1889. A comprehensive programme was prepared by Gill for these observations, including the co-operation

of the Yale, Göttingen and Bamberg observatories in the heliometer observations. A large number of observatories assisted in the meridian observation of the comparison stars. A very thorough discussion of the observations was made by Gill, the final value of the solar parallax which was obtained being 8″·804 with a probable error of 0″·005. A by-product of the investigation was an improved value of the mass of the Moon. The residuals from the observations showed a periodicity with a period equal to that of the "lunar inequality" in the Earth's motion. It is not the Earth, but the centre of gravity of the Earth and Moon, which moves in an approximate eclipse round the Sun. Using an assumed mass for the Moon, the effect of the motion of the Earth about the centre of gravity of the two bodies can be eliminated; but if the assumed mass is in error, the elimination is not complete. It was the residual motion, not eliminated, which Gill detected.

Gill's values both for the solar parallax and for the mass of the Moon, were not improved upon until the discovery of the minor planet Eros. Eros, at favourable oppositions, approaches the Earth more nearly than any other of the brighter minor planets, and is therefore a more suitable object than Iris, Victoria and Sappho. In 1901, at the first favourable opposition after the discovery of Eros, the asteroid was widely observed by international co-operation, the recently developed photographic methods being largely used. The results secured at various observatories were coordinated and discussed by Mr. Hinks, and values were derived for both solar parallax and mass of the Moon which had somewhat smaller probable errors than Gill had obtained. Eros on that occasion was only observable by observatories in the Northern Hemisphere, so that the Cape Observatory was not able to cooperate. The next favourable opposition of Eros—and one more favourable than that of 1901—occurred early in 1931. Again an extensive international programme of observation was organised. On this occasion, Eros was somewhat south of the equator at opposition and, though observable by observatories in both hemispheres, it was better placed for those in the Southern Hemisphere. On this occasion, the Cape Observatory secured a much more extensive series of observations than any other single observatory. The photographs obtained are at present being measured; and it is probable that the Cape Observatory plates by themselves will give values for solar parallax and for the mass of the Moon which surpass in accuracy those derived from the complete international programme of 1901.

The earlier connection of the Cape Observatory with survey

operations in South Africa has already been referred to. Soon after Gill's appointment to the Cape in 1879, he began to study the general question of a geodetic survey in South Africa. He had a great vision of a chain of accurate triangulation stretching across the African Continent, from the Cape to the mouth of the Nile and following approximately the 30th meridian of east longitude. Such an arc of triangulation might be extended, by an additional chain of triangles from Egypt, along the coast of Palestine and through the islands of Greece, to connect on to the Roumanian and Russian arc. If such a scheme of operations could be completed, the longest arc of meridian measurable in the world—105° in amplitude, from Cape Agulhas to the North Cape—would be measured. Bearing in mind that the longest measured arc of the meridian does not amount to 30°, it will be seen that the results would be of the greatest possible value to geodesy. The chain of triangulation across Africa has not yet been completed, but geodesists are hoping that when economic conditions improve a considerable extension northwards from the end of the arc that was completed under Gill's direction will be undertaken. Observations in the Cape Colony and Natal were commenced in 1883, as a result of a suggestion of Gill, and a triangulation of the two colonies was carried out between 1883 and 1892 by Colonel Morris, acting under the direction of Gill. In 1894, Gill urged upon Cecil Rhodes the importance of carrying out geodetic operations in Rhodesia. Gill's vision of the greatest measured arc of the meridian in the world, of which the Rhodesian section would be a link, was one which appealed to Rhodes. Though he declared that the provision of roads and bridges must come first, he took a great interest in the work when it was eventually commenced in 1897. The field-work was carried out under Mr. Alex. Simms, formerly a computer at the Cape Observatory, again acting under Gill's direction. The work was stopped in 1901, on account of the war, at the northern boundary of Southern Rhodesia. Gill's driving energy was again brought into play on the conclusion of the war to secure the survey of the Transvaal and of the Orange Free State. Lord Milner was sympathetic to the proposals, believing firmly as he did that good maps of a country are amongst the first essentials for good government. Gill prepared detailed proposals and estimates of expenditure for the survey and though his other duties at the time rendered it impossible for him to take over the executive direction of the work, he agreed to act as scientific adviser. The observations were carried out, under the direction of Colonel Morris, in 1903–04. Meanwhile, work had been recommenced in 1903 on the Rhodesian Survey and in the face of great difficulties, hampered

by grass fires, ravages of white ants, the sickness of Dr. Rubin, who was in charge of the operations, and with a continual struggle to secure funds for carrying on the work, it was brought to a completion in latitude $-10°$ just before Gill left for England in 1906 on leave prior to retirement. That the arc was carried through to this latitude, providing a continuous chain of 25° to Cape Agulhas, was due entirely to the indomitable energy, enthusiasm and persuasive powers of Gill. In the Union of South Africa, the work which Gill inaugurated is now carried on by the Government Trigonometrical Survey; primary and secondary triangulations have made great progress and a start has recently been made with a topographical survey.

In the later years of the last century, the pioneer work of Sir William Huggins on the spectra of the stars began to give a new orientation to astronomy. The new subject of astrophysics was being vigorously pursued in the Northern Hemisphere, but no observatory in the Southern Hemisphere was yet equipped for spectroscopic work. With a desire to remedy the condition of affairs the late Mr. Frank McClean in 1894 offered to present, for use in the Southern Hemisphere and primarily to the Cape Observatory, a 24-inch refractor with spectroscopic equipment, building and dome. This generous offer was accepted by the Admiralty and the telescope was erected and observations with it commenced in 1900. Until 1926, this instrument was used mainly for spectroscopic observations. The high dispersion of the 4-prism spectrograph rendered it particularly suitable for the study of the spectra of the later type stars, which show numerous fine lines. Accordingly, the programme of observations consisted largely of the measurement of the velocities in the line-of-sight of the brighter stars. In the course of these observations many stars were found to have variable line-of-sight velocity, and the variations in velocity of a considerable number of stars were studied in detail. The variations in velocity are in general due to relative orbital motion of two stars; normally, on account of the unequal brightness of the two stars, only one spectrum can be seen, though occasionally the two spectra are visible. The elements of the orbits were derived for many of the stars whose velocities were found to be variable.

The velocities actually observed are velocities relative to the Earth. The observed velocities will therefore vary, even though the velocity of the star is constant, as the Earth moves round the Sun. It is therefore customary to reduce the observed velocities to velocities relative to the Sun. To make this reduction, the distance of the Earth from the Sun must be assumed. Conversely,

if the velocity of the star is assumed to be constant, the observed velocities provide a means for the determination of this distance. This method of determining the solar parallax has been studied at the Cape. It is found to be capable of giving a determination of high accuracy, if a number of bright stars, having spectra which contain fine sharp lines, are kept under observation. The chief difficulty attaching to the method is the uncertainty in some cases whether the velocity of the star is or is not subject to minor periodic or irregular variations.

Detailed observations were made of various individual stars and novæ. It was fitting that the last series of observations to be made before the spectroscope was dismounted in 1926 were of the bright nova in the constellation Pictor, which appeared in May 1925. No bright nova has appeared in the sky since then, and as Nova Pictoris was not observable from any observatories in the Northern Hemisphere, it was fortunate that the high dispersion spectroscope of the Cape Observatory was available for its study, inasmuch as the nova presented many points of exceptional interest. Due to the early communication of its discovery to the Observatory by its discoverer, Mr. Watson, a South African amateur astronomer, and to the comparatively slow increase in brightness of the nova before maximum, it was possible to secure a series of photographs of the spectrum of the nova during the stage of increasing brightness. This stage is usually passed through so rapidly that the nova reaches its maximum brightness either before or soon after discovery The observations of Nova Pictoris established conclusively that the increase in brightness is accompanied by a rapid expansion of the outer layers of the star, the effective temperature not appreciably changing.

Since 1926, the 24-inch refractor has been largely employed in the determination of the parallaxes of stars in the southern sky by modern photographic methods, which have entirely superseded visual methods for this type of observation. With the exception of the determinations made at the Cape with the heliometer there were, at the time this programme was started, but few southern stars whose distances were known at all accurately. The *Catalogue of Stellar Parallaxes*, published in 1924 by Professor Schlesinger, contained only about 100 stars with observed parallaxes in the portion of the southern sky south of 10 degrees from the equator. The determinations at the Cape now reach nearly 500. This work has been carried on in co-operation with the Yale University Observatory southern station in Johannesburg, where also about 500 parallaxes have been determined. In this branch of work, the Southern Hemi-

sphere promises shortly to catch up to the Northern, in spite of the long start which the latter had and the larger number of observatories working upon the problem.

For many years Gill had been dissatisfied with the transit circle at the Cape Observatory. This instrument, which had replaced the old transit instrument and mural circles in 1855, was designed by Sir George Airy and was a duplicate of the Greenwich transit circle. It could not be reversed in its bearings and it was mounted in an observatory of such design that it was impossible to equalise the internal and external temperatures. The result of this was that refraction anomalies were produced and the observations were liable to systematic errors. Gill obtained approval in 1897 for the construction of a new transit circle and gave much thought to its design. The new instrument, which was completed in 1901, is a reversible transit circle with an object glass of 6 inches diameter, mounted in a housing designed to eliminate refraction anomalies by preventing horizontal stratification of the atmosphere. The instrument has since been in regular use for fundamental observations of star positions and has proved so satisfactory that the new transit circle now under construction for the Greenwich Observatory has been closely modelled upon the Cape instrument. A valuable feature of the Cape instrument consists in the employment of a system of meridian marks for controlling the azimuth of the instrument. Small illuminated holes or marks are placed to north and south of the instrument, in the focus of long-focus lenses (of about 300 feet focus); when viewed through the telescope these holes appear as fixed artificial stars. The marks and lenses are mounted over pits, excavated to a sufficient depth to reach the basic unweathered rock. At the bottom of each pit is placed an object glass, attached to a suitable mounting connected as directly as possible to the bed rock, with a mercury horizon beneath it. The vertical planes passing through the optical centres of the four object glasses define the lines of azimuth reference; the marks and long-focus lenses are set vertically above these by a simple optical method, light being sent through a hole attached to the mounting of mark or lens, which is in the focus of the lens at the bottom of the pit, and reflected back by the mercury horizon. These marks have extraordinary stability and provide an excellent control on the azimuth of the telescope. The azimuth can be determined from observations of the marks or from observations of stars near the pole. The former method determines the azimuth relative to points fixed on the surface of the Earth, the latter the azimuth relative to points fixed in the heavens. The axis of the Earth, however, has a slight

motion relative to the Earth itself, so that the azimuths determined by the two methods are not absolutely identical. Hough showed that by comparison of the two series of azimuths the actual motion of the Earth's poles could be determined. The motion so found was in close accordance with that given by direct observations of the variation of latitude. No better control over the stability of the azimuth marks could be desired!

The determination of star positions with the transit circle remains one of the few branches of astronomy in which photographic observations have not superseded visual But there is a progressive tendency to reduce the amount of visual observing even in this field and to transfer as much as possible to photography, which has the great advantage of economising time at the telescope. To determine star places from a photograph, the positions of several stars appearing on the photograph must be determined by visual observation. It is necessary to employ photographic lenses covering a large field in order to ensure that on each photograph there will appear a sufficient number of stars bright enough for convenient observation with the transit circle. The observations with transit circles are now generally limited to stars of the 8th magnitude or brighter, and the work of deriving the places of fainter stars is carried out by photographs with lenses covering an area of the sky of at least $5° \times 5°$. The Cape Observatory and the Yale University Observatory station in Johannesburg have a co-operative plan to observe the whole of the southern sky in this manner, determining the positions of all stars to at least the 9th magnitude. The work has been commenced recently but is not sufficiently far advanced for results to be published yet.

From this brief survey of some of the work on which the Cape Observatory has been engaged in the past or with which it is occupied at the present time, it will be evident, I think, that the Observatory has been closely connected with current developments in astronomy, and that it has successfully adapted itself to changing requirements. The number of observatories working in the Southern Hemisphere is much smaller than the number in the Northern, and it is inevitable that progress in some directions in the Northern Hemisphere should far outstrip that in the Southern. A responsibility is placed upon southern observatories to undertake observations which will meet the most pressing need of the moment, that does not rest to the same extent upon northern observatories. The progress of astronomy in certain directions may be seriously handicapped because lack of material for the greater part of the southern sky robs a statistical discussion of much of its weight.

In some respects the southern sky is of more interest and importance than the northern. It contains the brightest and most interesting portion of the Milky Way, in which the centre of rotation of the whole galactic system lies ; it contains also the two unique detached systems, the Large and Small Magellanic Clouds and the large obscured region termed the Coal Sack. These can only be studied from the Southern Hemisphere. Some American observatories have established southern stations in South Africa, the high veldt of which has extremely good conditions for astronomical observations, the Michigan Observatory Station concerns itself solely with double-star observations; the Harvard Observatory Station takes regular sky-patrol photographs which are used for the study of variable stars and other purposes ; the Yale Observatory Station is mainly occupied with stellar parallax observations. The Union Government Observatory in Johannesburg takes a prominent part in double-star and minor planet observations. But some branches of astronomy remain entirely neglected in the Southern Hemisphere for lack of suitable equipment. No spectroscopic work is being carried on at the present time ; included in this as a branch, no radial velocity determinations are being undertaken. For such purposes large reflectors are required. There is no doubt that the most pressing need of astronomy at the present time is the erection of one or more large reflectors in the Southern Hemisphere to be devoted to general spectroscopic observations. More than a century ago, the British Government established the Cape Observatory to supply the need, which had then made itself felt, of accurate places of the southern stars. May we hope that the present need will be met without undue delay by the erection of at least one large reflector, with spectroscopic equipment, somewhere in South Africa ?

The [illegible]rch the Greater Dome

JOSEPH PRIESTLEY (1733–1804), CHEMIST

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THE present year, since it marks the bicentenary of Joseph Priestley's birth, presents a suitable opportunity to review some of the judgments that have been passed on Priestley's work in experimental and theoretical chemistry.

As an experimenter, Priestley has been represented as an amateur and dilettante chemist, capriciously flitting from one haphazard experiment to another, and, despite the scientific absurdity of his method, having the good fortune to make classic discoveries; and as a theorist, he has been described as ingeniously weaving these discoveries into the tattered fabric of the phlogiston theory, to which he was so blindly devoted that no amount of hostile evidence could convince him of its falsity, and this even when all his contemporaries had long abandoned it in favour of the new chemical theory of Lavoisier. Both these views are inexact: the first is entirely so and is largely due to Priestley's practice of publishing his work immediately and to his habit of stressing the element of chance in scientific discovery, and the second requires qualification.

Pneumatic chemistry, in which Priestley achieved his greatest distinction, originated in the eighteenth century. The scientific investigators of the previous century, notably Boyle (*New Experiments Physico-Mechanicall, Touching the Spring of the Air, and its Effects*, Oxford, 1660 and 1662), had been interested mainly in the mechanical properties of air, and this interest perhaps accounts for their failure to discover the existence of a variety of "airs," chemically different from one another. Hales (*Vegetable Staticks*, London, 1727) in the early part of the eighteenth century followed in this tradition, since, although he obtained a number of gases by heating various bodies, he regarded them all as air containing different vapours, the air being supposed to act in the bodies as a kind of cement binding their small parts together. Black (*Experiments on Magnesia Alba, etc.*, Edinburgh, 1756) had shown the existence of an "air" different from common air and, by means of the balance,

had, without isolating it, traced it through various chemical changes. Following the mechanical tradition, he called it "fixed air." Brownrigg (*Phil. Trans.*, 1765, **55**, 218) had collected this "fixed air" from Spa waters by means of a primitive pneumatic trough and shelf; and Cavendish (*Phil. Trans.*, 1766, **56**, 141) had prepared "factitious airs," including "fixed air" and "inflammable air," and had momentarily isolated an "air" from spirits of salt, losing his product through its solution in the water over which he tried to collect it.

Priestley entered this field in 1768 at a time when it was sparsely cultivated. But, where others had barely scratched the surface, he began to plough deeply and deservedly reaped a richer harvest. His first researches were published in the *Philosophical Transactions*, but his papers grew too unwieldy for this medium and, moreover, they aroused such interest throughout Europe that he decided to publish these and all future investigations in book form Accordingly there appeared his *Experiments and Observations on Different Kinds of Air* (London, 3 vols., 1774, 1775 and 1777), followed by *Experiments and Observations Relating to Various Branches of Natural Philosophy*; *with a Continuation of the Observations on Air* (London, 1 vol., 1779, and Birmingham, 2 vols., 1781 and 1786) Priestley referred to these volumes as if they formed a continuous series, volumes I to VI, and for convenience his practice will be followed here. An abridgment in three volumes was published in 1790.

These volumes contain a wealth of experimental observation on gases with improved apparatus and technique and detailed descriptions of the first great series of discoveries in the history of pneumatic chemistry. But what interests us here is that they show Priestley the chemist at work, and careful reading of them dispels the illusion that he was a haphazard experimenter. They suggest to the reader that they are the laboratory notebooks of a chemist—even the mistakes are recorded—handicapped at least to modern eyes by a discursive literary style, although Priestley thought that he had considerably compressed his work and had forgone "the usual parade" indulged in by scientific writers.

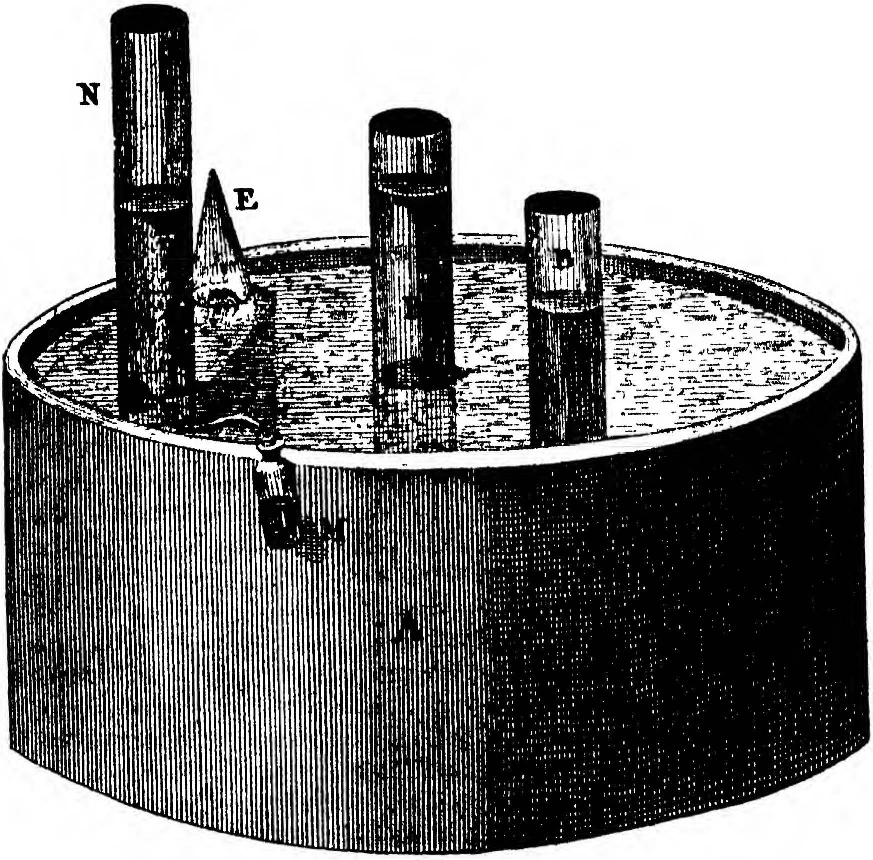
Priestley believed in immediate publication, even of work that was far from complete, because of the rapid progress and growing attention in the subject of "airs." "All unnecessary delays," he wrote, "in the publication of experiments relating to it are peculiarly unjustifiable" (I, vi). To keep a discovery secret and to ponder over it for the sake of increasing one's reputation through the possible establishment of a complete new system showed "want of a genuine love of science and of mankind." "As to myself," he

added, "I find it absolutely impossible to produce a work on this subject that shall be anything like complete. . . . In completing one discovery we never fail to get an imperfect knowledge of others, of which we could have no idea before, so that we cannot solve one doubt without creating several new ones. . . . Here there is not only a succession but an increase of new objects and new difficulties" (I, vii, viii). Priestley's volumes thus reveal him as an enthusiastic experimenter intent on the accumulation of new facts. One experiment suggests another and so on, but the series is rarely complete, which is not surprising in the infancy of pneumatic chemistry. Further experiments on a particular subject appear with additions and corrections in a later volume or volumes, and on account of this disorder those not properly acquainted with Priestley's methods of publication have been led to dub him haphazard experimenter, because they fail to find any system or synthesis when they turn hurriedly to his works. In this respect Partington (*Nature*, 1933, **131**, 348) has very justly compared Priestley with Faraday.

The *Introduction* to vol. I gives details of Priestley's experimental methods and illustrations of his apparatus. The pneumatic trough and shelf and the accessory apparatus are shown more elaborately and extensively than in the previous illustration in the paper read to the Royal Society (*Phil. Trans.*, 1772, **62**, 147), and there are numerous improvements and new devices, including several for studying the action of electric sparks on gases. Although Priestley says that his apparatus is "nothing more than the apparatus of Dr. Hales, Dr. Brownrigg, and Mr. Cavendish, diversified, and made a little more simple," this is merely an instance of his habit of scrupulously mentioning everyone to whom he stood in the slightest debt. Priestley had, in fact, considerably improved their apparatus in general convenience; and, where Cavendish (loc. cit., p. 160) had occasionally stored "fixed air" over mercury, Priestley now used it generally for the collection of "airs," particularly those soluble in water. Beyond this, he had forged a complete armoury of weapons for attacking this great problem; and by his skilful use of them he changed the whole face of chemistry.

Vol. I, Part I, deals with work done in and before 1772 and describes experiments on "fixed air," "inflammable air," "nitrous air," "acid air," etc. The experiments on "fixed air" were carried out at Leeds in the air above the vats in a public brewery adjoining Priestley's house. Some of them are very simple and include the extinguishing of lighted candles and burning wood held in the air. The most important observation made in this work was that the

solubility of "fixed air" in water could be turned to practical account for the preparation of an artificial mineral water, and Priestley's invention of this (the "soda-water" of to-day) was applied by the Admiralty as a remedy against sea scurvy. Priestley then tried the action of smokes and oil of vitriol on the "fixed air"



The first illustration of Priestley's pneumatic trough.

A, the trough, B, B, jars for collecting "airs", C, C, a shelf of flat stones, E, "a small glass vessel, of a convenient size for putting a mouse into it, in order to try the wholesomeness of any kind of air", M, "a small phial containing some mixture that will generate air This air passes through a bent glass tube inserted into the cork at one end, and going under the edge of the jar N at the other, the jar being placed with part of its mouth projecting beyond the flat stones CC for that purpose" (*Phil. Trans*, 1772, **62**, 252).

above the vats, and finally he used ether. At this point the experiments terminated owing to "a very disagreeable circumstance . . . For all the beer, over which this experiment was made, contracted a peculiar taste." Thereafter, he prepared his "fixed air" by the action of oil of vitriol on chalk.

Priestley also tried to prepare "fixed air" by heating chalk or powdered limestone in a gun-barrel. Air was produced "in great plenty," but only a half of it was "fixed air," the rest being "inflammable air," which, he noted, "burns blue, and not at all like that which is produced from iron, or any other metal, by means of an acid" Here, almost at the outset of his work, he had obtained carbon monoxide, the gas that caused great confusion in chemistry until the end of the century, when it was differentiated from that other kind of "inflammable air," hydrogen Priestley observed that it had a different smell! Here, too, he showed that plants restored air that had been vitiated by respiration He isolated "nitrous air" [nitric oxide], prepared by the action of "nitrous acid" [nitric acid] on various metals, and studied its properties The diminution that occurred when this air was mixed with common air had already been observed by Hales, but Priestley applied it quantitatively to measure the "goodness" of air, since the diminution was "very nearly, if not exactly" in proportion to the air's fitness for respiration His method consisted in adding 1 measure of "nitrous air" to 2 measures of common air contained over water and noting the contraction.

This part also describes the isolation and discovery of "acid air" [hydrogen chloride] by a repetition of Cavendish's abortive experiment (*see* p. 18), which Priestley made successful by collecting the gas over mercury instead of water Later he called it "marine acid air"

Here, too, in *Miscellaneous Observations* (p. 155 f.), we find that Priestley had actually obtained oxygen at some date before November 1771. He writes · "In one quantity [of air] which I got from saltpetre a candle not only burned, but the flame was increased." This he thought "very extraordinary and important, and, in able hands, may lead to considerable discoveries"; and he referred to it again in 1775, when his own able hands had made the considerable discovery.

Part II of this volume deals with work done in 1773 and the beginning of 1774. The first section describes the discovery of "alkaline air" [ammonia], which Priestley prepared by heating "volatile spirits of sal ammoniac," just as he had prepared "acid air" by heating "spirits of salt." The one experiment suggested the other. He found that the new air was slightly inflammable and that, when it was mixed with "acid air," it produced white clouds of sal ammoniac. He also records that common air was diminished by electric sparks and that an acid was produced in the process; and further reports that, when iron filings or liver of sulphur acted

on "nitrous air," a contraction occurred and a new "air," which he later called "diminished nitrous air" [nitrous oxide], was produced, and that a candle burned freely in this air. He now found a better method of making "acid air," namely, by warming common salt with oil of vitriol. He tried to prepare the "spirit of nitre" in the form of air, but it attacked the mercury over which he tried to collect it. He adds: "I do not know any inquiry more promising than the investigation of the properties of nitre, the nitrous acid, and nitrous air. Some of the most wonderful phenomena in nature are connected with them, and the subject seems to be fully within our reach" (p. 273).

The *Preface* to vol. II states that the subject of "airs" is now being studied throughout Europe and "bids fair to be farther advanced than any other in the whole compass of natural philosophy"; and that, "in reality, this is not now a business of air only, as it was at first; but appears to be of much greater magnitude and extent, so as to diffuse light upon the most general principles of natural knowledge, and especially those about which chymistry is particularly conversant." Priestley again stresses the incompleteness of his work, the subject is merely "pretty well opened," and the experiments reported suggest as many more. No conjectures, speculations or hints are to be advanced in this volume, "because I have not yet sufficiently reflected upon the facts that suggest them."

The first important discovery to be recorded here is that of "vitriolic acid air" [sulphur dioxide], which Priestley after certain failures and mishaps prepared by heating mercury with oil of vitriol. But the main interest in this volume is the discovery of "dephlogisticated air" [oxygen]. The section describing this has been quoted so often by historians of chemistry that it does not need detailed repetition here, but it must be emphasised that, while this discovery has more than any other given Priestley lasting fame, his method of reporting it in this place has seriously injured his reputation by misleading careless readers. He begins by stressing once more the element of chance and this, torn from its context, is quoted against him without his pertinent comment that the circumstance of chance playing a greater part than design in discovery "does not appear in the works of those who write *synthetically* upon these subjects; but would, I doubt not, appear very strikingly in those who are the most celebrated for their philosophical acumen, did they write *analytically* and ingenuously." This observation is a very true one; for discoverers almost invariably and instinctively rationalise their work before publication and the element of chance is forgotten. Most discoveries are in some degree due to it: and,

although no one would say that Faraday discovered electro-magnetic induction deliberately, some critics seem to expect Priestley to have made his discovery in this way and are too ready to depreciate it because he was, to use a word much favoured by him, " ingenuous " enough to stress the part played by chance, not merely in this but in all scientific discoveries.

Priestley now goes on to say that, having obtained a new and more powerful burning lens, he was able to carry out a series of experiments that he had previously projected, " which, in theory, appeared very promising," and in which he proposed to examine the " air " obtained by heating various bodies " With this apparatus," he says, " after a variety of other experiments, an account of which will be found in its proper place, on the 1st of August, 1774, I endeavoured to extract air from *mercurius calcinatus per se* [mercuric oxide, prepared by heating mercury in air]; and I presently found that, by means of this lens, air was expelled from it very readily. Having got about three or four times as much as the bulk of my materials, I admitted water to it, and found that it was not imbibed by it. But what surprised me more than I can well express, was, that a candle burned in this air with a remarkably vigorous flame. . . ."

Some historians of chemistry have written about this experiment as if Priestley heated *mercurius calcinatus* because he could not lay his hand on any other substance at the moment and state that, as a confirmed phlogistonist, he ought never to have tried it. This is certainly not the case. Priestley was not, as appears below, so deep in the toils of the phlogiston theory as to let it control his experiments, and, moreover, he had previously obtained " fixed air " from (impure) calces. It was not a chance experiment: the whole section shows it to have been one of a series deliberately planned. And far too much has been made of his surprise. It was the properties of this air and not its production that surprised him. His customary tests on a new " air " consisted in seeing if it was soluble in water and if a candle burned in it. The " airs " that he had previously discovered, namely, " acid air," " alkaline air," and " vitriolic acid air," were all soluble in water, and both the acid " airs " extinguished a lighted candle, while " alkaline air " was slightly inflammable. But this new " air " was different: it was insoluble in water and a candle burned in it " with a remarkably vigorous flame." Priestley was, for a time at least, at a loss to account for its properties, but he was not, nor did he ever hint that he was, amazed at its production. Finally, for well-known reasons, he called it " dephlogisticated air " ; and this and other

experiments convinced him that air was "not an elementary substance, but a composition."

Priestley thought at first that the *mercurius calcinatus* "must get the property of yielding this kind of air from the atmosphere" by extracting the "spirit of nitre" from the air (pp. 38, 41); and shortly afterwards gave this up in favour of the view "that all the constituent parts of the air were equally, and in their proper proportion, imbibed in the preparation of this substance" (p. 41).[1] There is not much excessive devotion to the phlogiston theory in either of these attitudes.

Here also Priestley states (p 36) that during his visit to Paris in October of the same year he frequently mentioned this discovery to Lavoisier and others, "who, I dare say," he adds, "cannot fail to recollect the circumstance." He repeated this in vol II (pp. 108–9) of the abridged edition of 1790 (*Dic. Nat. Biog.* gives this as the first occasion[2]). Lavoisier took no notice, but claimed independent discovery, stating that "this species of air was discovered almost at the same time by Mr. Priestley, Mr. Scheele, and myself" (*Elements of Chemistry*, trans. R Kerr, Edinburgh, 1790, p. 36 and in later editions). Lavoisier certainly had no title to it. Priestley repeated his assertion after Lavoisier's death in both editions of his *Doctrine of Phlogiston Established, etc.* (1800 and 1803).

The great discovery was made on August 1, 1774, and some authorities give it as Sunday, August 1. Holmyard (*Makers of Chemistry*, Oxford, 1931, p. 172) calls it "a warm Sunday afternoon," a time when "one's mental faculties are not as a rule at their best" (otherwise, why would a phlogistonist be wasting his time trying to get air out of a calx ?). Miss M. M. Haslam has pointed out to me that August 1, 1774, was a Monday and I have confirmed this, so that Priestley, the divine, can no longer frown at Priestley, the chemist, for breaking the Sabbath in the worldly pursuits of science.

It is also stated in various places that the discovery of oxygen was made at Bowood, Calne, Wiltshire, the country residence of Priestley's patron, the second Earl of Shelburne, but in a letter to Dr. Price (*Phil. Trans.*, 1775, **65**, 390) Priestley refers to "the pure air I discovered in London." It appears therefore that oxygen was discovered at Shelburne House (later Lansdowne House), in Mayfair.

There seems to be an impression that the passages cited above constitute Priestley's first public announcement of his discovery. If

[1] Lavoisier, too, held this view at first.

[2] Otherwise, in every respect an accurate account and a just estimate of Priestley's work and ideas.

there were no such impression, we should expect historians to refer to an earlier announcement. But they do not, although there is an earlier one. In a letter to Sir John Pringle, P.R.S., dated March 15, 1775, and read to the Society on May 25, 1775 (*Phil. Trans*, 1775, **65**, 384), Priestley gave a fairly detailed account of his experiments on heating solid bodies and collecting the "airs" given off. Since the dedication page of vol. II is dated November 1775, this letter contains the first public announcement of the discovery of oxygen, and it is therefore of considerable historical interest and importance and especially so for the view that is being put forward here. In the letter Priestley refers to the series of experiments in which he had planned to heat various bodies "with the solar rays." He states that he has heated metals, salts, calces, etc., and has found "that different substances yield very different kinds of air by this treatment." He continues: "The most remarkable of all the kinds of air that I have produced by this process is one that is five or six times better than common air for the purpose of respiration, inflammation, and, I believe, every other use of common atmospherical air. As I think I have sufficiently proved that the fitness of air for respiration depends upon its capacity to receive the phlogiston exhaled from the lungs, this species may not improperly be called *dephlogisticated air*. This species of air I first produced from *mercurius calcinatus per se*, then from the red precipitate of mercury, and now from red lead." On testing it, he found that "a quantity of this air required about five times as much nitrous air to saturate it as common air requires." Further, "a candle burned in this air with an amazing strength of flame; and a bit of red-hot wood crackled and burned with a prodigious rapidity, exhibiting an appearance something like that of iron glowing with a white heat and throwing out sparks in all directions." Also, a mouse lived much longer in it than in common air. Priestley adds: "My conjectures concerning the cause of these appearances are as yet too crude to lay before the Society", he thought that "nitrous acid" was the basis of common air and that nitre was a product of atmospheric decomposition, "but," he adds, "it is possible I may think otherwise to-morrow."

As stated above, this was Priestley's first public announcement of his discovery. Its quotation here is pardonable, since it has no great currency among historians of chemistry. If it had, we should perhaps hear less of the legends about chance and surprise and phlogiston and so on; and if Priestley had written in this way and in these terms in the *Experiments and Observations*, vol. II, there would have been none to call him lucky.

It is, too, not generally known that Priestley prepared his "dephlogisticated air" by another method, namely, by heating the calces with a candle-flame in a glass tube, connected by means of a delivery tube with a pneumatic trough and gas jar containing mercury. In the letter to Dr. Price, dated April 1, 1775, cited above, he states that he used this method with various substances and refers to an apparatus illustrated in vol. I. There does not, however, appear to be any mention of this in vol. II.

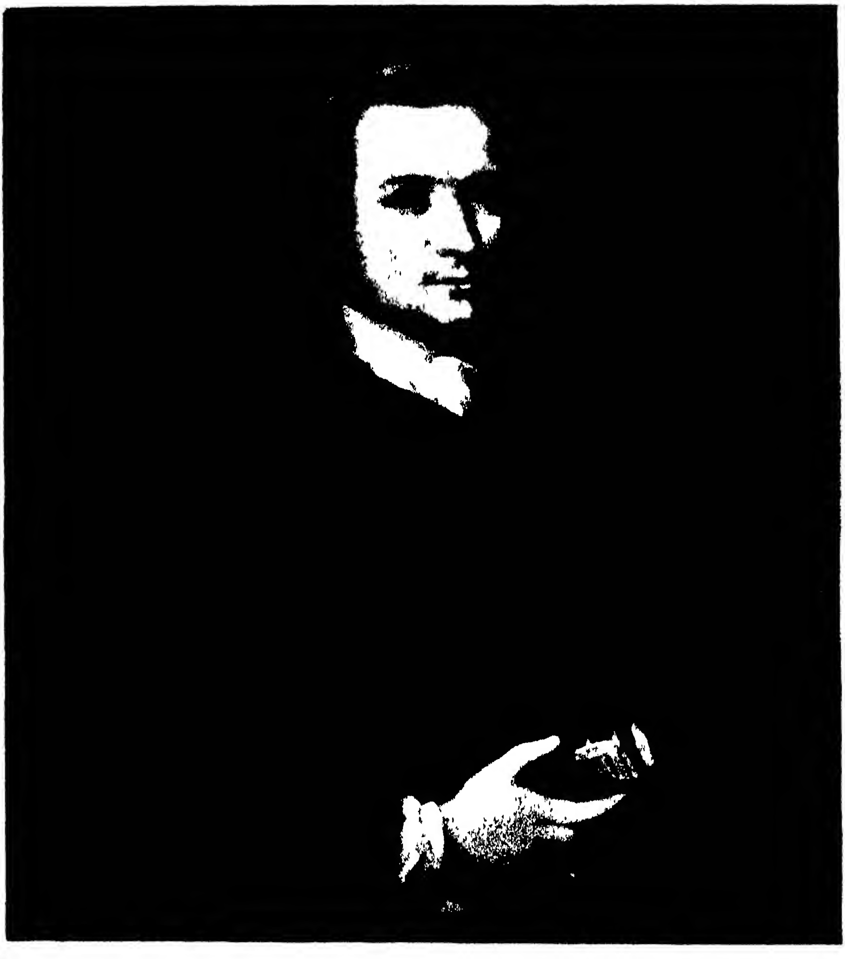
Before proceeding, it must be added that Priestley breathed some of the new "air" himself and, as he says, "fancied that my breast felt peculiarly light and easy for some time afterwards," that he thought it might be useful in the treatment of diseases of the lungs or, perhaps, become "a fashionable article in luxury," and suggested that it could be used in bellows "to augment the force of fire to a prodigious degree."

Vol. II further contains accounts of two other notable discoveries, the decomposition of "acid air" and of "alkaline air" by electric sparks, and describes the isolation of "fluor acid air" [silicon fluoride].

Vol. III, *Preface*, comments on the great progress made in this new subject and adds that for the complete understanding of it "we must wait for the result of farther researches, and more discoveries." Priestley says, too, that his attention will be otherwise engaged for some time, but that, should he have any opportunity to prosecute his experiments, he will publish his results at once, "as I shall think myself," he says, "or any other person, much to blame, if, from any personal considerations, we should delay the publication of any new fact that might facilitate the progress which is now so rapidly making in this branch of science" (p. vii). He would like to be able to give some general theory of the different kinds of air, but "investigations are by no means sufficiently advanced for any thing that would be tolerably complete of the kind" (p. x). In this new field, facts are more valuable than opinions and he wishes no stress to be laid on any opinions he may express.

This volume contains a host of additional experiments on substances previously studied, some data on the thermal expansion of "airs," and an account of the preparation of "nitrous acid vapour" [nitrogen peroxide] in an impure state from "nitrous acid" [nitric acid] and bismuth and its collection by displacement of air. Priestley made the notable observation that the colour of the "nitrous acid vapour" deepened on heating.

Vol. IV, *Preface*, states that "speculation without experiment



Joseph Priestley (1733-1804) The Leeds portrait (c 1763)

The earliest portrait of Priestley Artist unknown The present location of the original is unknown, but a photographic copy from which the above is reproduced, was recently found by Mr W Cameron Walker in the Library of the Royal Society

(Reproduced by kind permission of the Royal Society)

has always been the bane of true philosophy" (p. vii), and urges readers "to consider new facts only as discoveries, and mere deductions from those facts as of no kind of authority" (p. xi).

This volume describes some startling experiments on "Attempts to preserve animal Substances in nitrous Air." Priestley wanted to find out whether his previous observation that animal bodies did not putrefy in this air could be applied "for culinary purposes." His results were not "very favourable." Meat kept in "nitrous air" did not putrefy, but it became "very offensive both to the nostrils *and the palate*!" He kept the bodies of two pigeons in this air for six weeks, then cooked one of them; the taste was "on the whole, unpleasant." The other was replaced in the air for over three months; when cooked, the flesh "exclusive of the smell, had little or no taste." "My friend, Mr. Magellan,"[1] adds Priestley, "who was with me at the preparation of them had not so bad an opinion of this piece of cookery as I had." They were indeed redoubtable experimenters.

Here also Priestley showed that an aqueous solution of "vitriolic acid air" containing "earth of alum" after six months exposure in an open vessel deposited crystals of alum. Thus "volatile vitriolic acid" [sulphurous acid] was capable "of being brought back to the state of common vitriolic acid." In further experiments, he heated aqueous solutions of "vitriolic acid air" in sealed tubes for many months, observed the formation of crystals as the heating progressed and identified the crystals as sulphur.

Vol. V, like vol. IV, contains no theoretical speculations. Pp. 395–98 report in a letter from Priestley's friend, Warltire, the "good chymist," the deposition of dew when "inflammable air" was fired in closed glass vessels with common air, an observation that subsequently led to Cavendish's synthesis of water.

Vol. VI records the discovery that metallic calces could be reconverted to metals by heating them in "inflammable air" (p. 5), and the preparation of an "inflammable air"[2] by heating finery cinder (iron oxide) with charcoal (p. 109). Priestley also describes various experiments on the diffusion of gases, in one of which he observed that, when a bladder containing "inflammable air" was placed in a large jar of "dephlogisticated air," the "airs" diffused into one another.

This, with the exception of certain memoirs that we shall mention below in discussing Priestley's theoretical ideas, completes the tale of his classic experimental work. It is enough to say here that, by his discovery of seven gases, namely, oxygen, ammonia, hydrogen

[1] J. Hyacynth de Magellan, F.R.S. [2] Carbon monoxide.

chloride, nitric oxide, nitrous oxide, nitrogen peroxide and sulphur dioxide, and by his magnificent experimental advances, Priestley had contributed more towards the establishment of modern chemistry than any of his predecessors or contemporaries.

Turning to Priestley's theoretical outlook and general scientific attitude, we find little to criticise and a great deal to praise, provided we mentally betake ourselves to the period in which he lived. Priestley tried to be always on guard against hasty theorising, "lest," he says on one occasion, "in consequence of attaching myself to any hypothesis too soon, the success of my future inquiries might be obstructed," to which he adds: "I shall be ready to relinquish any notions I may now entertain, if new facts should hereafter appear not to favour them" (I, 177). This attitude is general throughout his work. "These experiments," he says, "appear to me to furnish matter for much speculation, and farther experimental inquiry. Till this be done, all conjecture concerning them must be very much at random. I therefore defer making any at present" (II, 240). "Speculation," he says elsewhere, "is a cheap commodity New and important facts are most wanted, and therefore of most value" (III, xxx).

In most of his explanations, however, Priestley invoked the phlogiston theory, but he was not dogmatic about it and several times he was on the point of abandoning it. Indeed, he did abandon it for a time, as will appear later.

The gain in weight of metals on calcination Priestley ascribed to the taking up of "fixed air"[1] and water by the calx (I, 187). He would not accept the view that the causticity of lime was due to the addition of phlogiston from the fuel used in the burning of the limestone from which it was produced (I, 238). He would have nothing to do with any belief in the levity of phlogiston. "That phlogiston," he wrote, "should communicate absolute levity to the bodies with which it is combined is a supposition that I am not willing to have recourse to, though it would afford an easy solution of this difficulty," namely, that "phlogisticated air" was lighter than common air (I, 267). Later (II, 312), he wrote: "I never had any faith at all in that doctrine of the principle of levity."

The opinion that Priestley accepted the levity of phlogiston is still, however, current in some quarters. A. S. Russell in the bicentenary article on Priestley in *The Listener* (March 8, 1933, p. 358), says that "in theory he was little better than a half-wit. . . . The increase in weight when the metal was burned, he admitted; but he sophistically declared that that was what should have been

[1] Later, he said it was "dephlogisticated air."

expected. Phlogiston must be a 'principle of levitation,' its weight negative, so that when it left the metal the product, of course, was heavier . . . he seemed to have the kind of involved mind which would describe a credit balance at the bank as a negative overdraft." This is so grossly incorrect that comment is unnecessary.

When Lavoisier began to express his changing ideas with greater clarity and definiteness and when these ideas became more widely promulgated, Priestley began to take a more active part in the controversy and, although he often found himself at variance with the new theory, he repeatedly stated that he preserved an open mind on the matter. His discovery that metallic calces could be reconverted to metals by heating them in "inflammable air" appeared to him to provide very strong evidence in favour of the phlogiston theory, since he found no other product of this reaction, "the inflammable air . . . being absorbed by them *in toto*, without decomposition"; and he could not determine the change in weight of the calces on account of losses through sublimation, but, it must be admitted, he expected to find a gain in weight, since, as he says: ". . . were it possible to procure a perfect calx, no part of which should be sublimed and dispersed by the heat necessarily to be made use of in the process, I should not doubt but that the quantity of inflammable air imbibed by it would sufficiently add to its weight" (*Phil. Trans.*, 1783, **73**, 408). This, it should be remembered, was written at a time when Lavoisier stood alone, unsupported by any contemporary chemist.

Priestley expressed himself similarly in the *Experiments and Observations* (VI, 3), stating that he had been "much inclined" to accept Lavoisier's views, but this discovery convinced him that Kirwan's proof of the identity of "inflammable air" and phlogiston was correct. He was, however, much more strongly influenced by Watt and it appears that for some time Priestley accepted Lavoisier's views and that it was Watt who won back his allegiance to the phlogiston theory. Repeating Lavoisier's experiments on the action of red-hot iron or charcoal on steam, Priestley wrote: "I was determined to repeat the process with all the attention I could give to it; but I should not have done this with so much advantage, if I had not the assistance of Mr. Watt, who always thought that M. Lavoisier's experiments by no means favoured the conclusion that he drew from them. As to myself, I was a long time of opinion that his conclusion was just, and that the inflammable air was really furnished by the water being decomposed in the process. But though I continued to be of this opinion for some time, the frequent repetition of the experiments, with the light which Mr. Watt's

observations threw upon them, satisfied me at length that the inflammable air came principally from the charcoal or the iron" (*Phil. Trans.*, 1785, **75**, 291).

Further, in vol. VI (p. 111), Priestley refers to his recent discovery that "inflammable air" was produced when finery cinder was heated with charcoal as "decisive against the hypothesis of Mr. Lavoisier," since, according to the latter, there was no phlogiston or anything that could produce water in either of the reactants, but, adds Priestley, "supposing the reality of phlogiston, and its constituting a part of metals, of charcoal, and of inflammable air, the experiment is very intelligible." It was a result that perplexed everyone but phlogistonists. Priestley, of course, regarded finery cinder as iron that had imbibed water in place of its phlogiston, whereas Lavoisier maintained that it was an oxide. This result drove Priestley back to the phlogiston theory and in three memoirs on the composition of water (*Phil. Trans.*, 1788, **78**, 147 and 313, and 1789, **79**, 7), he returned to the view that all gases contained water and that, when "inflammable air" and "dephlogisticated air" were exploded, this water was precipitated, and rejected the anti-phlogistic explanation that it was the combination of these gases that produced water, although, he says, he formerly "made no difficulty in receiving it myself" and "was myself a believer in it." What puzzled Priestley here was the appearance of acid and he would not accept Cavendish's explanation that this was due to contamination of the reacting gases with "phlogisticated air." A few years later he argued that experiments pointed now one way and now the other, and added, "I have myself been very differently inclined at different times" (*Phil. Trans.*, 1791, **81**, 213).

At this point in his scientific career Priestley became the victim of political persecution and he emigrated to America, where he subsequently died in 1804. During his exile he carried out further experiments, but America was a long way off in those days and Priestley had lost immediate contact with the leaders of scientific thought. Incidentally, it might be mentioned, he declined an invitation to occupy the chair of chemistry in the University of Pennsylvania.

Before leaving England Priestley had in the concluding pages of the abridged edition of the *Experiments and Observations* (III, 563) stated his attitude to the contending chemical theories. "As I have," he wrote, "been more than once upon the point of abandoning it [the phlogiston theory], and in my sixth volume actually declared in favour of the decomposition of water, I should not feel much reluctance to adopt the new doctrine, provided any new and

stronger evidence be produced for it. But though I have given all the attention that I can to the experiments of M. Lavoisier, etc., I think that they admit of the easiest explanation on the old system."

The production of "inflammable air" from finery cinder and charcoal still remained a difficulty to the new theory; and in the reaction between steam and charcoal Lavoisier (op. cit., p. 87) maintained that the inflammable gas "cannot possibly have been disengaged from the charcoal, and must consequently have been produced from the water."

Priestley's attack on the new views appeared in his *Considerations on the Doctrine of Phlogiston, etc.* (London, 1796), and in more extended form in *The Doctrine of Phlogiston Established, etc.* (Northumberland, U.S., 1800). In the opening pages of this book, Priestley says: "No person acquainted with my philosophical publications can say that I appear to have been particularly attached to any hypothesis, as I have frequently avowed a change of opinion, and have more than once expressed an inclination for the new theory, especially that very important part of it the decomposition of water, for which I was an advocate when I published the sixth volume of my *Experiments on Air*" (p. 3). He reverts again to the reaction between finery cinder and charcoal. In this reaction both theories were agreed that "inflammable air," *i.e.* hydrogen, was produced. But, argued Priestley, if hydrogen is a constituent of water, it can only be produced in a reaction where water or some substance containing water is present; and yet, according to the new theory, there is no water in either of the reactants, since finery cinder is said to be oxide of iron and therefore contains only iron and oxygen, and charcoal can contain no water because it is made "with the greatest degree of heat that can be applied." The new theory cannot explain the reaction, but the old theory can, since, according to its principles, "the finery cinder containing water, as one of its component parts, gives it out to any substance from which it can receive phlogiston in return. The water, therefore, from the finery cinder uniting with the charcoal makes the inflammable air,[1] at the same time that part of the phlogiston from the charcoal contributes to revive the iron" (p. 18). Similarly, "inflammable air" of the same kind is produced by the action of steam on red-hot charcoal. Priestley had already (*Experiments and Observations, etc.*, 1790, III, 506) concluded that finery cinder consisted of iron that had imbibed water and lost its phlogiston.

Continuing, Priestley says that the followers of Lavoisier have

[1] Priestley considered that all gases contained water, and "inflammable air" was water plus phlogiston (from the charcoal).

had to find water somewhere in the reactants, and some of them say it is present in the finery cinder, which is an abandonment of the fundamental principles of their theory, "which absolutely requires water to be decomposed in passing over hot iron," and others find it in the charcoal. To these latter he now addresses himself, referring them to the experiments of Woodhouse (*Trans. Amer. Phil. Soc.*, Philadelphia, 1799, **4**, 464), who heated one ounce of finery cinder and one ounce of charcoal in separate crucibles for five hours at a red heat, mixed them in a red-hot iron mortar while they were still red-hot, triturated them with a red-hot pestle, poured them on to a red-hot piece of sheet iron and instantly put them into a red-hot gun-barrel, from which there then issued 142 ounce measures of "inflammable air" with 10 per cent. of carbonic acid gas. It is significant of the prevailing confusion of the period that the opening sentence of the paragraph in Woodhouse's paper describing the experiment begins, "To ascertain the quantity of hydrogenous gas afforded by charcoal and finery cinder", and it is worth noting that Priestley had performed the experiment fourteen years earlier (*Phil. Trans.*, 1785, **75**, 300), and had found 10 per cent. of "fixed air" in the product.

Woodhouse commenting on his result said that "this experiment has puzzled all the advocates of the antiphlogistian system, to whom it has been mentioned. Many consider it a powerful blow at the new doctrine, and every person explains it in a different manner." Priestley, after quoting from Woodhouse, wrote that "nothing more could have been done to exclude all water from each of the substances previous to their mixture; and yet we immediately find the effects of water, as much as if water itself had been employed instead of the finery cinder, which no doubt contained it," and, since Woodhouse had adopted a half-way attitude in the current controversy, Priestley added: "This experiment, I should have expected, might have converted the ingenious author of it himself." And, criticising the views of Berthollet and Fourcroy (*Ann. de chim.*, 1798, **26**, 302), he says that, since they regard water as an extraneous substance in charcoal, it is not a constituent part of the charcoal and is, therefore, separable from it as water by the mere application of heat; and he asks of what use they think the finery cinder is in the process, since they have no occasion for its oxygen, which, however, it loses in the reaction.

"When I first made this experiment," says Priestley in concluding this topic, "with charcoal and finery cinder, I remember Mr. Watt said it was one that the Antiphlogistians could never reconcile to their hypothesis; and the more I consider it, and the

objections that have been made to it, the more reason I see to be of his opinion" (p. 22).

Here, too, Priestley disposes of his troublesome and ill-informed critic, Maclean, who, commenting on Priestley's detection of water and acid in the explosion of "inflammable air" with "dephlogisticated air," had praised the large scale of the French chemists' experiments and scorned Priestley's "very trifling quantities of materials." Large-scale experiments are not, replied Priestley, on that account more accurate, and "when I can produce but a few drops of a strong acid, and as often as I please, from the very same materials from which I am told I ought to get only pure water, what is it to me whether they produce gallons? . . . Though I have not gallons of this liquor, I have some ounces which no antiphlogistian would care to drink" (pp. 47, 49).

These two problems, the production of "inflammable air" in the experiments with finery cinder and the formation of acid in the composition of water, must be cleared up, argued Priestley, before the new theory can be solidly founded; and, "tho' the title of this work expresses perfect confidence in the principles for which I contend, I shall still be ready publicly to adopt those of my opponents, if it appear to me that they are able to support them. Nay, the more satisfied I am at present with the doctrine of phlogiston, the more honourable shall I think it to give it up upon conviction of its fallacy" (p. 77).

In 1801, however, this long confusion between hydrogen and carbon monoxide was brought to an end, when Cruickshank (*Nic. J.*, 1801, **5**, 1) showed that the inflammable gas produced in the reduction of metallic oxides with charcoal was not hydrogen but an oxide of carbon. He isolated it, determined its density, exploded it with oxygen and showed that it was thus converted into carbon dioxide, and named it "gaseous oxide of carbon." His views were accepted slowly and Priestley found much to criticise in them, especially since Cruickshank asserted that his results provided a sufficient answer to Priestley's objections to the new chemical theory.

Priestley considered that Cruickshank's discovery shifted the ground of the argument for both sides, since Cruickshank was abandoning the view that water was necessary for the formation of "inflammable air"; and he thought that Cruickshank was abandoning the new theory as well in supposing that the oxygen from the finery cinder united with the carbon of the charcoal to form, not "fixed air" as the theory demanded, but an inflammable air. This seemed to him to be throwing over the new theory for the sake of explaining one of its difficulties, and if no better defence was

forthcoming, "I shall," he said, "soon conclude that it is incapable of any just defence" (*New York Medical Repository*, 1802, **5**, 393). And in a letter, dated April 12, 1802 (*ibid.*, 1803, **6**, 24), he wrote that Cruickshank's new oxide "must be different from all the other oxides, none of which are combustible, being substances already saturated with oxygen," and complained that his opponents abandoned their theory in its most fundamental principles when they got into difficulties with it. "If," he wrote, "substances be combustible in proportion to their affinity to oxygen, and their consequent readiness to unite with it, this air, which is inflammable, must be of this class, and therefore the very reverse of the oxides, which are saturated with oxygen and incapable of receiving more." Evidently, to Priestley a combustible oxide was a contradiction in terms.

In a second edition of his *Doctrine of Phlogiston Established* (Northumberland, U.S., 1803), Priestley confirmed his attitude as expressed in the earlier edition and added sections dealing with Cruickshank's views. In this he says that "one of the most eminent of [the antiphlogistians], in conversation with a friend of mine at Paris, said that I had kept them for some time in torture by my objections to their system, but that they were intirely relieved by Mr. Cruickshank" (p. 28). But he would have none of it; and insisted that his opponents were accepting an explanation that was essentially an abandonment of their theory and that they were boasting "of the discovery of a new oxide, when they are unable to prove that it contains a particle of oxygen, and when its obvious properties show that it belongs to a class of substances the very reverse of oxides. If the discovery, as it is called, relates to the substance, it belongs to me. All that they can pretend to is having given a better account of the nature of it, and with what success they have done this, let the impartial reader judge" (p. 32).

This was Priestley's last appearance on the stage of chemistry on which for over thirty years he had played a great and honourable rôle. He died in the following year. It is hoped that this account of his theoretical views will go some little way towards eradicating the false opinion that he was blindly devoted to the phlogiston theory, since even in his last argument logic was not wholly with his opponents.

Throughout his long life, Priestley was a prolific writer. The entries under his name in the British Museum Catalogue fill nearly twenty columns of theological, educational, philosophical and scientific items; and *Observations on the Increase of Infidelity* stands cheek by jowl with *The Impregnation of Water with Fixed Air*. He

devoted the greater part of his time to theological studies and his extraordinarily extensive and varied scientific work was done in leisure hours ; he was continually going to press and, on his death-bed, one of his last actions was the correction of proof-sheets.

In closing this account of Priestley's chemical labours, we may aptly quote from the *Preface* to the first volume of his *Experiments and Observations*. He writes : "I would observe farther, that a person who means to serve the cause of science effectually, must hazard his own reputation so far as to risk even mistakes in things of less moment. Among a multiplicity of new objects, and new relations, some will necessarily pass without sufficient attention ; but if a man be not mistaken in the principal objects of his pursuits, he has no occasion to distress himself about lesser things. In the progress of his inquiries he will generally be able to rectify his own mistakes ; or if little and envious souls should take a malignant pleasure in detecting them for him, and endeavouring to expose him, he is not worthy of the name of a philosopher, if he has not strength of mind sufficient to enable him not to be disturbed at it. He who does not foolishly affect to be above the failings of humanity will not be mortified when it is proved that he is but a man."

AEROPLANE SOUNDS

By C. F. B. KEMP, A.R.C.S., B.Sc., D.I.C.

A KNOWLEDGE of the properties of the sound-field surrounding an aircraft finds immediate application in problems relating to location, detection and silencing. The subject is of growing interest, not only on account of these problems, the importance of which need not be stressed, but also because theoretical considerations involve a study of some little explored branches of acoustics. In addition, special difficulties of much interest arise in the technique of experimental investigation.

The characteristic sound associated with aircraft in general is produced mainly by two sources, the open ends of the exhaust pipes and the airscrew. The contributions from these sources are of comparable physical magnitude, the airscrew sound having marked directional properties while the exhaust sound may be directionally or uniformly radiated according to the type of engine and the exhaust system used. The nature of the exhaust sound is amenable to theoretical treatment and guiding principles for the determination of the fundamental frequency and of the directional properties have been evolved by M. D. Hart [1].

At the present time, three exhaust systems are commonly found. These are (i) the ring exhaust used with static radial engines such as the Bristol "Jupiter"; (ii) the dual manifold system used with V-engines, *e.g.* the Rolls-Royce "Kestrel"; and (iii) the triple manifold system found with "broad-arrow" type engines, as typified by the Napier "Lion." The dual manifold arrangement is a convenient example for showing the application of the principles mentioned. If the crankshaft of a four-stroke engine makes R revolutions per second, each cylinder fires R/2 times per second and each exhaust port thus becomes a source of sound consisting of a train of harmonics with R/2 for the fundamental frequency. When all the cylinders (n), in one block of the engine, exhaust into a single manifold, the distance between the various ports is usually small compared with the length of the manifold and this, coupled with the high temperature of the gases in the pipe and

consequent high speed of sound therein, causes the disturbance at the free end to be sensibly the same as if all the gases entered in one annulus. Such an arrangement results in the suppression by phase opposition of all the frequency components except those which are integral multiples of nR/2. Hence the open end of the exhaust manifold produces a sound of fundamental frequency nR/2 and its harmonics. Whereas the cylinder fundamental frequency, R/2, is always sub-audible, the fundamental frequency of the exhaust system is always in the audible part of the spectrum: *e.g.* for a 12-cylinder engine arranged in two blocks of six cylinders and making 2,100 r.p.m., R/2 = 17·5$\sim$ and nR/2 = 105$\sim$. Now, in a two-block engine, successive explosions occur in alternate blocks, so that at any instant the disturbances at the outlets of the two exhaust manifolds differ in phase by π and the exhaust system is acoustically equivalent to a fluctuating doublet of fundamental frequency nR/2, with a line joining the outlets of the manifolds as axis, this axis being invariably parallel to the transverse axis of the aircraft. It may be shown that at distances from the aircraft great compared with the distance, l, between the exhaust outlets, the pressure-amplitude of the mth harmonic in a direction making an angle ψ with the longitudinal axis is proportional to

$$\left\{1 + \left(\cos \frac{m\pi n\mathrm{R}l \sin \psi}{a}\right) (-1)^m\right\}^{\frac{1}{2}}$$

where a is the speed of sound in air. Clearly, different harmonics have different directional properties and the same engine may give rise to various distributions of exhaust sound according to the spacing of the manifolds and the speed of the engine. In practice, the latter variable need not be considered, for, in level flight, aircraft engines are always run between narrow speed limits. For the particular directions $\psi = 0°$ and $\psi = 180°$, *i.e.* in the direction of flight and along the slip-stream, the pressure-amplitude is seen to be zero for the odd harmonics and a maximum for the even harmonics, whatever the values of n, l and R. In other directions, these factors are operative. Specimen polar curves for the distribution of the sound in a horizontal plane are given in Fig. 1 and refer to a "Kestrel" engine running at 2,250 r.p.m. with exhaust outlets 3 feet 10 inches apart.[1] The polar surfaces representing the distribution in three dimensions are obtained by revolving these polar curves about the axis of the doublet, *i.e.* about the transverse axis of the aircraft.

[1] In the nomenclature here adopted, the 1st harmonic is identical with the fundamental, the 2nd harmonic with the octave and so on.

In any chosen direction the composition of the exhaust note must depend not only upon the directional properties of the acoustical doublet but also on the composition of the sound close to each separate manifold. The latter is known to be rich in harmonics, and this might well be expected, for the wave form must be related to the shape of the engine indicator diagram, which being impulsive in character, necessarily resolves into a long train of important harmonics. The amplitudes of these are modified by the acoustical properties of the manifold and it is not improbable that the nature of any particular exhaust sound could be completely predicted from the indicator diagram and the geometry of

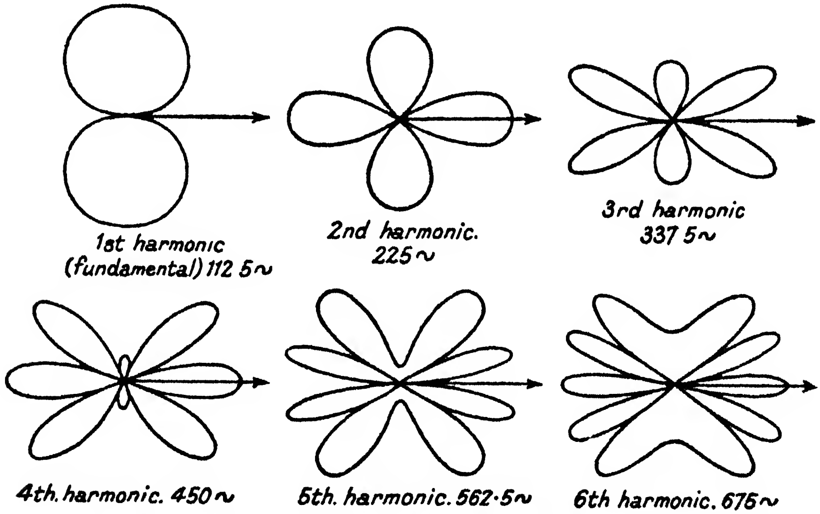


FIG. 1.—Polar diagrams of the sound from a "Kestrel" Engine (2 blocks of 6 cylinders) running at 2,250 r.p.m. (The arrow-head denotes the direction of motion.)

the exhaust system. So far as the author is aware, however, no calculations on this basis have been published.

The directional properties of the sound from a triple manifold system are far more complicated but can be determined by a process similar to the above, the acoustical equivalent being now a fluctuating triplet with phase differences of $2\pi/3$ between the individual sources. Much of the complication is due to the fact that for reasons of construction, the exhaust outlets are disposed in the form of a scalene triangle, so that the distribution is asymmetric. The static radial engine with ring exhaust may be regarded as a single block of cylinders exhausting into one manifold, so that the fundamental frequency is again $nR/2$, but n is now the total number of cylinders in the engine. If the ring exhaust has

only one outlet, the sound is uniformly radiated; if there are two outlets there is again a complex but determinable distribution. Hart has further shown that the polar surfaces so calculated require slight modification to account for the translational motion of the aircraft. The modified distribution is no longer symmetrical about the axis of the doublet but is perceptibly displaced against the direction of motion. The ideal conditions postulated in the theory are never quite realised in practice, for the exhaust outlets are not in free air, but comparatively close to reflecting surfaces such as the wings and fuselage. For the lower frequencies, however, the results of experiment are in substantial agreement with the predictions of theory. A notable exception occurs astern, where the sound output is considerably lessened by virtue of the acoustical opacity of the slip-stream. Ahead of the aircraft, the exhaust sound is very powerful and is responsible for the predominant "hum-note" heard by an observer when an aircraft approaches. In the case of the Kestrel engine, this is the second harmonic with frequency 210$\sim$, well within the audible region and easily distinguished.

The airscrew as a source of sound has been treated theoretically by several investigators with incomplete success, but there is a steadily increasing amount of experimental data which should prove useful in the verification of any more comprehensive theory. The passage of the blades through the air gives rise to a sound having for its fundamental frequency the product of r, the revolutions made per second by the shaft, and B, the number of blades on the airscrew. This frequency and its harmonics form what has been termed the "sound of rotation," and although this is not the only sound emitted it is the one with the greatest energy content. Other constituents in the total sound arise from flexural vibrations (discussed by Fage [2]) and from the aperiodic shedding of eddies from all parts of the blades. It may be said that so far as the frequencies of the latter can be determined, they are mostly above 1,000$\sim$, and that in a frequency spectrum they would appear as bands covering a range up to the audible limit. These aperiodic constituents are thought to give rise to the tearing and hissing sounds so noticeable close to an airscrew.

The sound of rotation was first studied in 1919 by Lynam and Webb [3], in an attempt to establish a relationship between pressure-amplitude and tip-speed for a family of airscrews yielding the same thrust at the same forward speed and in particular to discover whether any discontinuity is to be expected when the tip-speed exceeds the speed of sound. The airscrew was regarded as being

acoustically equivalent to an annular system of sources and sinks, coaxial with the airscrew and fluctuating with the frequency rB, there being a progressive phase lag around the annuli of $1/2\pi r$ seconds per radian. Two working hypotheses were adopted, the first being that the annulus of sources was as far ahead of the airscrew as the annulus of sinks was behind it. Application of the principle of retarded potential leads to an expression [1] for the pressure-amplitude which indicates that at distances great compared with dimensions of the source-sink system, there is zero sound output along the axis of the airscrew and in the plane of rotation, while maximum output occurs in the directions $\psi = 60°$, 120°, 240° and 300° approximately (see Fig. 2), these values changing slightly with the speed of rotation but preserving their symmetrical distribution. In the second hypothesis the ring of sinks was removed to an infinite distance behind the airscrew and the ring of sources placed just ahead of the airscrew. The corresponding expression for the pressure-amplitude is now a little simpler [2] and again yields zero output along the axis, but a maximum in the plane of rotation (Fig. 2).

It was pointed out that the truth might be found in a combination of these hypotheses and recent experimental results tend to show that such may be the case. Of the two distributions, the second is the more in accordance with experience and precisely this expression has been developed by Hart,[3] who makes no other assumption than that the air in the path of the blades is subject to a periodic disturbance of a general nature. Hart's expression refers to the maximum pressure-amplitude within the cycle of the disturbance at a distant point due to blade elements at a stated

[1] $$A_m = kJ_{Bm}\left(\frac{Bm\omega X}{a}\sin\psi\right)\sin\left(\frac{Bm\omega Y}{a}\cos\psi\right)$$

where A_m is the maximum pressure-amplitude of the mth harmonic within its own period.

J_{Bm} is Bessel's function of order Bm;
ω is the angular speed of rotation of the airscrew;
a is the speed of sound;
X is the mean radius of the annuli (assumed equal to three-quarters of the blade length, *i.e.* the doublet axes pass through the locus of the centre of pressure);
Y is the perpendicular distance of the sources and sinks from the plane of rotation of the airscrew;
and ψ is the angle between the direction of motion of the aircraft and the direction in which A_m is required.

[2] $$A_m = \frac{k}{2}J_{Bm}\left(\frac{Bm\omega X}{a}\sin\psi\right)$$

[3] loc. cit.

mean radius (X) from the airscrew centre. Thus, elements situated at different radii theoretically produce different distributions, but it may be shown that the polar curves do not vary in general form provided the wave-length of the harmonic considered is greater than the diameter of the airscrew The effective distribution actually lies between that for elements near the blade tips and that for the least radius elements which can be appreciably productive of sound. Although the total pressure-amplitude in any direction may be written down in the form of an integral, the integration cannot, in our present state of knowledge, be evaluated owing to the presence of " constants " which are unknown functions

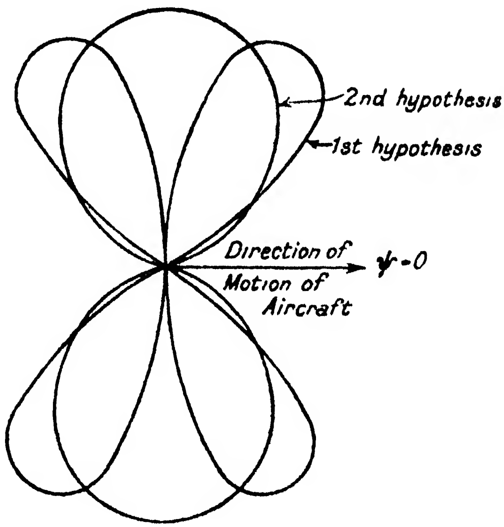


FIG. 2.—Theoretical polar distribution of air-screw sound.

of the radii of the elementary annuli—they are, in fact, dependent on the configuration of the blades. Further, it is possible, though not established, that the phase of the disturbance may vary along the length of the blade.

The polar surfaces which represent the distribution of the sound in three dimensions are, in the case of an airscrew, obtained by rotating the polar curves of Fig. 2 about the axis of rotation of the screw. Modifications are again necessary to account for the effect of translational motion and Hart has shown that maximum output may then occur slightly ahead or slightly behind the plane of rotation according to circumstances. Experiments, to be described later, have always shown the pressure-amplitude to be a

maximum about 30 degrees behind the plane of rotation, under the conditions of measurement.

The theory of airscrew sound is not yet sufficiently advanced for the pressure-amplitude in a chosen direction to be given as a function of the geometry or of the aerodynamics of the airscrew, although its dependence on certain factors is known as the result of experiment. If it be expressed in geometrical terms, the factors pitch, diameter, number of blades and speed of rotation must be included; if it be expressed in aerodynamical terms, the relevant factors will be the horse-power absorbed and the efficiency of the airscrew, with possibly certain geometrical terms as well. That so little progress has been made in this direction may be partly ascribed to our present limitation of knowledge regarding the acoustics of moving sources. It is not possible, for example, to state the velocity-potential at a distance, due to a source which is in motion, a matter of fundamental importance.

With regard to the other sounds emitted by aircraft, these are mostly important only at close range. Certain of them, such as the sound of the airscrew eddies, the singing of stay-wires and whistling sounds generally, may penetrate to moderate distances and be heard by reason of the particular sensitivity of the ear for the frequency-range concerned. Their energy content is, however, small. The remaining sounds which never penetrate far, may be classified as miscellaneous engine noises, natural vibrations and forced vibrations of parts of the aeroplane structure.

We are now in a position to consider the methods adopted in experimental work which has for its object the determination of the polar distributions of the various frequency-components and the relative importance of these components as affected by the introduction of the relevant variables. The reception of the sound and its recording present no serious difficulty. The apparatus may comprise a microphone, amplifier and oscillograph of known overall performance, in which case the wave-form of the sound is photographed and subsequently analysed by computation. If one particular frequency is of interest, the microphone itself may be tuned or a tuning circuit incorporated in the amplifier. The oscillograph may then be replaced by some direct reading instrument such as a thermionic voltmeter, the deflexion of which will be proportional to the r.m.s. pressure-amplitude. Lastly, the whole of the sound may be received, amplified and then analysed by some "search-tone" method (*e.g.* that due to Grützmacher [4]) while the sound is actually being emitted. The choice of method is dependent on the conditions of experiment, but the last named

is more applicable to problems of average frequency-distribution throughout the spectrum than to accurate determinations of harmonic composition. It has recently been employed in a modified form by Schuchmann, Eisner and Rehm [5]. The basic principle of "search-tone" methods is briefly as follows. The sound to be analysed is received by a microphone, amplified and then mixed with a pure tone (termed the "search-tone") generated by an oscillator. The frequency of the search-tone is slowly varied, but with constant amplitude, throughout the whole range of audio-frequencies. Whenever the frequency of the search-tone approaches a frequency in the sound to be analysed, a difference tone is produced and this may be manifest in the form of slow oscillations of the needle of a meter, the amplitude of the oscillation being proportional to the amplitude of the component discovered. The apparatus is very elaborate and to obtain results having any pretension to accuracy, the process of searching must be performed very slowly, otherwise the difference-tone oscillations have insufficient time to build up.

There are numerous reasons why it is not practicable to collect data for the verification of theories of sound emission by taking observations on the sound made by an aircraft in flight. These are worth considering in some detail. (1) It is a common practice to gear the airscrew to the crankshaft in a ratio such that the frequencies in the airscrew sound are enharmonically related to those in the exhaust sound. For example, in the Rolls-Royce "Condor" engine, which has twelve cylinders arranged in two blocks, this ratio is 1 : 0·477, so that for an engine speed of 1,800 r.p.m. the frequencies in the airscrew sound are 28·6, 57·2, 85·8, 114·4, 143·0, 171·6, etc., while those in the exhaust sound are 90, 180, 270, etc. Repetitions of wave-form cannot occur, and the necessary process of enharmonic analysis is tedious to a prohibitive degree, having regard to the large number of analyses required in order to plot polar curves. (2) Although many of the frequency-components may be individually studied by means of a resonant microphone or tuned circuit, this procedure cannot be followed when the frequency under consideration is separated from an adjacent frequency (in either harmonic train) by an amount less than the frequency-change in either component due to the Doppler effect. In the above example, the third harmonic (85·8$\sim$) in the sound from the airscrew cannot be separated from the first harmonic (90$\sim$) in the exhaust sound. As the speed of an aircraft increases, so more of the frequencies come into this category, for a simple calculation shows that for a ground speed of 240 m.p.h. the

total change in frequency for each component is about an octave. (3) Observations corresponding to different values of ψ, the "aspect angle," are necessarily made at different distances from the aircraft. When ψ is small and the distance therefore great, correction of the results to a standard distance by application of the inverse square law of intensity is inadmissible, because very little is known about the effects of atmospheric absorption, which is a function of both distance and frequency. (4) Attenuation due to temperature refraction and wind refraction occurs and can be corrected for only if the meteorological conditions are known quantitatively at all heights. (5) The wave-form at any instant must be accurately correlated with the position of the aircraft, due allowance being made for "lag of sound." (6) The prevailing wind may cause the direction of flight to be inclined to the longitudinal axis of the aircraft, resulting in a false estimation of ψ. When this effect is absent there still remains yawing (*i.e.* inherent slow oscillations of the aircraft about its normal axis) which causes the polar surfaces to oscillate also. All these factors are important and lead to the conclusion that experiments conducted along these lines would involve excessive organisation and yield results of doubtful accuracy.

Much may be achieved by simpler means. To obtain the polar surfaces of distribution it is, for reasons of symmetry, usually sufficient to analyse the sound received at points on a circle having for its centre the geometrical centre of the particular sound source under investigation. This may be done by moving the microphone around a stationary aircraft at a moderate distance. Results so obtained apply strictly to the "zero rate of advance" condition, which is but a special case in any general theory of sound emission. The testing or formulation of a theory even for this one condition would be a considerable step forward and on these grounds the procedure is justifiable. Besides overcoming the difficulties associated with the use of an aircraft in flight, this method has the added advantage that most of the factors entering into a complete theory can be introduced without change of engine. Thus, airscrews of different diameter may be fitted, variable-pitch airscrews may be used and all airscrews may be run over a wide range of rotational speeds. The equipment used by the author consists of a tethered aircraft, stripped of its wings, tail-plane and rudder, and mounted over a silencing pit into which the exhaust gases may be led when it is desired to record the sound from the airscrew alone. This method of silencing is very effective, for oscillograph records of airscrew sound taken under these conditions exhibit perfectly

repeating wave-forms even when the gear ratio causes the fundamental frequencies of the exhaust and airscrew to be enharmonically related. Obata and Yosida [6] have published much information on the subject of airscrew sound derived from experiments with models. The difficulty here is that the sound of the driving mechanism, usually a large electric motor, must be screened, and this involves the presence of reflecting surfaces which must badly distort the polar curves and so affect the result of analysis in any chosen direction. The conditions postulated in the various theories are ideal; that is to say, the sound is assumed to be propagated through a homogeneous medium and the sources of sound to be remote from any reflecting or diffracting bodies. While the first condition is reasonably fulfilled in experiments made at zero rate of advance, adherence to the second condition is only approximate on account of the proximity of the fuselage to the exhaust openings and the presence of the engine behind the airscrew The engine and its nacelle (that part of the aeroplane structure which contains the engine) being of irregular shape, the acoustical equivalent of the airscrew must be modified, but to an incalculable extent. Further, the tips of the blades pass close to the ground where local disturbances are possibly formed. There is, however, no alternative but to neglect these factors at present.

In Fig. 3 are given the polar curves for the first six harmonics in the sound from a particular two-bladed airscrew [7]. These were obtained at zero rate of advance using a silenced engine and each frequency was studied separately by the tuned circuit method. The sound was received by a calibrated condenser-microphone placed on the ground at a distance of 300 feet from the airscrew boss. The radii vectores represent the pressure-amplitude existing at the microphone diaphragm, where reflection is practically complete, the diaphragm being arranged horizontally and as nearly flush with the ground as possible. The pressure-amplitudes which would exist in a progressive wave have therefore half these values. It will be seen that in general, the lower the frequency the greater is the amplitude and that there is a marked tendency for maximum output to occur from 20 to 30 degrees behind the plane of rotation. A subsidiary maximum appears in front of this plane and in the case of the first and second harmonics takes the form of a spur. As the order of the harmonic rises, the sound output ahead of the plane of rotation increases in importance, relative to the lateral output. Isolation of the frequencies allowed the steadiness of the pressure-amplitudes to be observed over a considerable period with the engine running at constant speed. It was found that the

output was always steadiest in the region of maximum output and that least fluctuation occurred for the lowest frequencies. Along the axis of the slipstream the output was small, but exceedingly variable, while much unsteadiness was noticed near $\psi = 60°$, *i.e.* in the region of the re-entrant portions of the polar curves. The existence of the spur at $\psi = 30°$ in the polar curve of the first

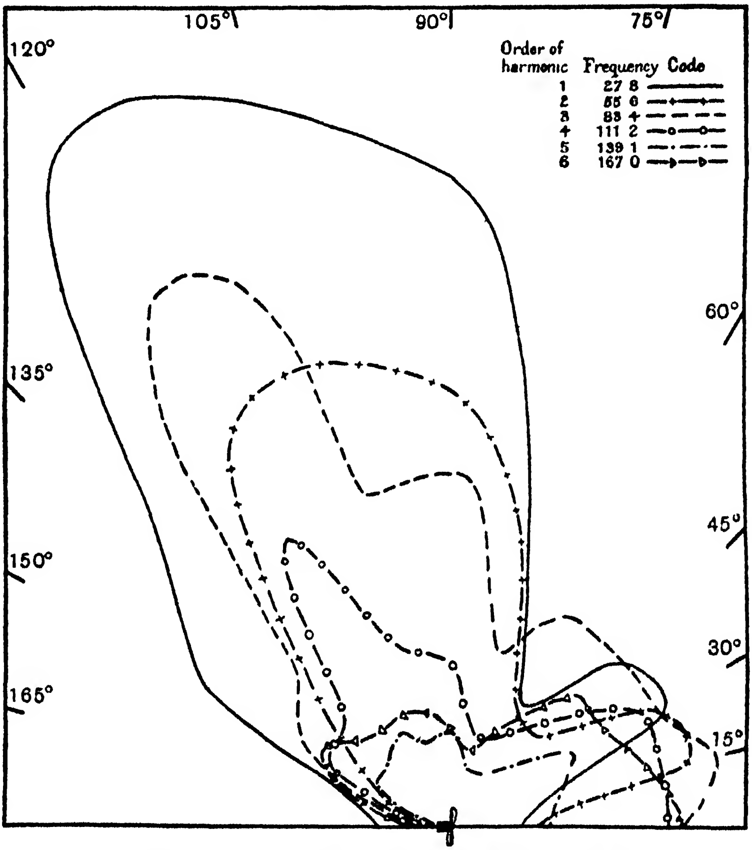


FIG. 3.—Polar curves for distribution of airscrew sound. Scale: 1 cm. = 0·84 dyne/cm.² (r.m.s.). (Airscrew pitch at pressure face, 3200 mm.; blade-diameter 4500 mm.; engine speed 1,750 r.p.m.).

harmonic had already been demonstrated by Paris [8] (who used a Tucker hot-wire microphone), and a possible explanation given of it in terms of the alternative hypotheses of Lynam and Webb. In this explanation both source-sink systems are co-existent but of different strengths, and the expression for the pressure-amplitude is similar in form to those of Lynam and Webb. It can be made to represent the observed distribution by the simultaneous adjust-

ment of two constants, the relative strength of the two systems and the distance of the sources and sinks from the plane of the airscrew. The theoretical significance of this equivalent acoustical system is obscure, but it is interesting that the two hypotheses can be combined at all to give a result very nearly in accordance with experiment. Unfortunately, it has been impossible to reconcile this arrangement of sources and sinks with observations made upon the second and higher harmonics.

The polar distribution of airscrew sound appears not to have received attention from other investigators, probably because its existence was unsuspected. Obata and Yosida,[1] for example, have constructed empirical formulæ for the effects of pitch and speed of rotation by an oscillographic study of the sound from model airscrews rotating under conditions of environment which must have seriously altered the distribution. While their results can be regarded as qualitatively correct the actual formulæ may require some revision. For a given pitch, the amplitude of the fundamental increases with the speed of rotation, but the rate of increase is greater in the plane of rotation than elsewhere. The results are consistent with a relation of the type $\log A = LR + M$ where L and M are constant for a particular aspect. In the plane of rotation, the effect of increasing the pitch is to increase the amplitude, and the greater the pitch, the greater the rate of increase of amplitude with speed of rotation.[2] Regarding the harmonic constitution of airscrew sound, it is usually found that the fundamental frequency is physically the most important and that the higher order harmonics have progressively decreasing pressure-amplitudes. The upper frequencies do not lend themselves to accurate computation by normal methods of harmonic analysis, but may be measured by "search-tone" methods. Theodorsen [9] has analysed the sound from model airscrews in this manner. There are reasons which indicate that these upper constituents are of an aperiodic nature and uniformly radiated around the airscrew. Since there is a profusion of them within the frequency range to which the ear is most sensitive, this may explain why a polar diagram of loudness levels, obtained by an audiometer, does not exhibit the marked directional effects associated with the components of lower frequency. It is commonly found that such a polar diagram is of an approximately circular type, the loudness level ahead of the airscrew being a few decibels higher than the average level,

[1] loc. cit.

[2] The relationship found is $\log A = \alpha R + \beta e^{k\psi} + \gamma$ where α, β, γ and k are constants.

while in and near to the plane of rotation there is a slight decrease in loudness.

As might be expected, increase in tip-speed is accompanied by increase in loudness, but the manner of this increase has received most attention at close range only, the object being to apply the results to problems of cabin-silencing. There is very little available information as to the relationship which holds at moderate distances (*i.e.* a few hundred feet) and none at all as to that at long distances. At moderate distances, Obata finds that the loudness level increases linearly with the tip-speed over the range of tip-speeds considered, which was from 450 ft./sec. to 850 ft./sec. although individual observations deviate appreciably from this simple relation. The author, using a Barkhausen "buzzer" audiometer and working over the more restricted range of 450 ft /sec. to 650 ft./sec. found that only ahead of the airscrew was such a simple interpretation of the observations justified, while for other aspects the plotted points could be represented only by formulæ of a highly artificial character, varying with the aspect. Unfortunately, methods of estimating loudness levels have not been standardised ; for example, Obata's result is the mean of two series of observations based on the recognition of a balance of physiological intensity between the airscrew sound and a pure tone, this pure tone being 256∼ in one case and 512∼ in the other, while the author employed an approximately pure tone of frequency 800 Some observers have used 1,000∼ and others have discarded the "balance of physiological intensity" methods in favour of "drowning" methods, in which the loudness of the pure tone is decreased until it just ceases to be heard in the presence of the airscrew sound. It is a common experience that aircraft when equipped with four-bladed airscrews are considerably quieter at a distance than when equipped with the more usual two-bladed type. This is merely because the latter must rotate faster in order to attain the same aerodynamical performance assuming the power unit to be the same. It is not known definitely, however, whether the four-bladed airscrew produces a disturbance of less physical magnitude than a two-bladed airscrew developing the same thrust at the same forward speed. Lynam and Webb's work indicates that such is likely to be the case. So far as is known, no quantitative acoustical experiments concerning the sound from airscrews having tip-speeds greater than the speed of sound have been described. At such speeds, an observer in or near to the plane of rotation, is aware of a crackling sound, which spreads on either side of the plane of rotation as the tip-speed increases. The phenomenon was discussed by the

late Professor G. H. Bryan [10], who pointed out that when the speed of sound is exceeded, "the sound waves from three different positions of the source will reach the observer simultaneously during a portion of the period of revolution, and at the beginning and end of this portion a sudden change of the potential will occur, giving rise (theoretically) to infinite condensation at these instants," and this infinite condensation (or ratio of the increase in air density to the original air density) is suggested as the cause of the crackling sensation. When the tip-speed (v) of the airscrew is equal to the speed of sound (a), the phenomenon is confined to the plane of rotation, but when v exceeds a the phenomenon is observable within a region having boundaries which everywhere make an angle $\alpha = \cos^{-1}\frac{a}{v}$ with the plane of rotation.[1] Professor Lamb [10] has drawn attention to the analogous instance of the high-speed projectile in this connection. Each airscrew element having a speed greater than that of sound is accompanied in its rotation by an *onde de choc* which causes two abrupt changes in density when its conical wave-front sweeps past an observer. A B-bladed airscrew produces 2B such changes and these are necessarily associated with abnormally high pressure-amplitudes of the higher harmonics to which the ear is especially sensitive. This might also explain the aural sensation experienced.

In view of the fact that the principal sources of sound in an aircraft are known to have directional properties which are different for different frequencies, it is surprising that with a little practice many types of aircraft may be identified by their characteristic sound. The wave-form is known to vary greatly with the aspect, and yet this faculty of recognition may be successfully exercised for all aspects. The finer distinctions between the *timbres* of certain allied musical instruments are dependent on the strength and disposition within the frequency spectrum of the higher harmonics and overtones and the same is possibly true here. Since the wave-lengths of the higher harmonics are small compared with the dimensions of the various sources, they tend to be uniformly radiated and together tend to constitute an unvarying portion of the total wave-form. Undoubtedly, recognition is also largely aided by periodic fluctuations in intensity. These may have various causes, the most common being the production of beats.

[1] Prof. Bryan's expression for the condensation was $S \propto \frac{1}{a^2 d^2} \frac{a v \cos \alpha}{a - v \cos \alpha}$ where d is the distance of the observer from the source.

In the case of multi-engined aircraft the beats originate in the slightly different rotational speeds of the separate engines. When there are only two engines the beat frequency is usually well defined and may be due to the airscrews or the exhaust systems according to aspect; on occasion there may be a complicated succession of beats from both sources. The beat frequency is clearly not constant for the same aircraft. When there are more than two engines, so many beat frequencies are present at one time that their definition is poor. The sound from a single-engined aircraft may also contain beats, in this case between a component in the exhaust sound and one in the airscrew sound. When they occur they are of constant frequency but yield less intensity fluctuation than those produced by sources of the same kind. The use of a non-simple gear ratio is necessary for the production of beats from a single-engined machine; otherwise, adjacent frequencies are everywhere too far separated for their difference to be recognised as a beat at all. At moderate range this may sometimes, however, be heard as a rapid flutter and it has been suggested that a similar sensation may also arise from the presence of residual vibrations of the fundamental cylinder frequency R/2 which, as has been explained, is always sub-audible in the sense that the ear can appreciate it only as a rapid sequence of impulses. Intensity fluctuations are also possible by reason of oscillations of the aircraft as a whole while recovering from slight disturbances encountered during flight. The complex nature of the distribution of the exhaust sound, for example, is such that oscillations of the order of a few degrees can result in appreciable changes in both physical and physiological intensity.

In the interests of the personal comfort of the occupants of civil aircraft, the subject of cabin silencing is now receiving detailed attention and the considerable improvements already made have been achieved, not by suppressing the noises at the source, but by the judicious relative location of the passenger accommodation and the various sound sources and by suitably treating the cabin walls. To suppress any noise at the source is only partially possible and even then exceedingly difficult. Furthermore, the complete elimination of any one source of sound is not instrumental in bringing about a notable reduction in overall loudness level, for in an aircraft, the sound sources (airscrew, exhaust, engine, etc.) each have a high loudness level, and since loudness levels are not additive, the final loudness level is not immensely greater than the loudness level of any of the constituents considered separately. For example, if it is known that in a particular aircraft, the airscrew develops as much sound energy as the exhaust system, the

complete silencing of either of these sources will give a reduction of only 3 db. If, when this is done, it is discovered that the remaining source supplies as much energy as the miscellaneous sounds, *e.g.* engine clatter and partition drumming, the elimination of this remaining source will again bring about a reduction of only 3 db. and so on.

ACKNOWLEDGMENT

My thanks are due to the Royal Engineer Board for permission to publish this account of our knowledge of aircraft sound and of the investigations which have yet to be undertaken. Fig. 3, which is extracted from a paper by the author, is reproduced here by permission of The Physical Society.

REFERENCES

1. M. D. Hart, *Aero. Research Committee Reports and Memoranda*, No. 1310 (1930).
2. A. Fage, *Proceedings R.S.*, **A, 107,** 456–8 (1925).
3. E. J. Lynam and H. A. Webb, *Aero Research Committee R. and M.*, No. 624 (1919).
4. M. Grutzmacher, *Z. f. tech. Phys.*, **10,** 570 (1929).
5. F. Eisner, H. Rehm and H. Schuchmann, *Elektrische Nachrichten-Technik*, **9,** 323–33 (1932).
6. J. Obata, Y. Yosida and S. Morita, *Report No.* 79 *of the Aero. Research Institute*, Tokyo Imperial University (1932)
7. C. F. B. Kemp, *Proc. Phys. Soc.*, **44,** 151–65 (1932).
8. E. T. Paris, *Phil. Mag.*, **13,** 99 (1932).
9. T. Theodorsen, U.S.A. National Advisory Committee for Aeronautics. *Report*, No. 395 (1931).
10. Prof. G. H. Bryan and Prof. H. Lamb, *Aero. Research Committee R. and M.*, No. 684 (1921).

THE CENTENARY OF THE ROYAL ENTOMOLOGICAL SOCIETY OF LONDON

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On May 3, 1833, a few British naturalists met in J. G. Children's rooms in the British Museum, Bloomsbury, to found the Entomological Society of London. On May 3, 4 and 5 of this year the Society celebrated its centenary. At the opening ceremony in the rooms of the Royal Geographical Society it was announced that His Majesty had been graciously pleased to grant the Society the privilege of being known henceforth as the Royal Entomological Society of London. The applause which greeted this announcement and also another, made a few minutes later, that Professor E. B. Poulton had been elected Honorary Life President, indicated that the success of at least the social side of the occasion was ensured. The scientific side of the Society's activities was displayed in the conversazione held in its own rooms at 41 Queen's Gate on the same evening. The officers of the Society are much to be congratulated on the successful adaptation of the meeting-room and library to a first-class exhibit of all branches of modern entomology.

A link with the past was appropriately found in an exhibit made by the Society itself of some interesting volumes from its library. These included some early hand-painted figures of insects and also the Society's obligation book which is signed by all who are admitted as fellows, and includes such names as those of Kirby, Darwin, Wallace and Bateson. Curiously enough there was not much evidence in the exhibits of what has been the chief activity of the last hundred years, *viz.* the classification and description of species. The taxonomist is always liable to be somewhat retiring and to feel himself in the same relation to other workers as the bricklayer to the architect. In Entomology at least, this feeling is misplaced, for the multiplicity of insect species makes it more than ever essential that identification should be as far as possible rapid and reliable. The only strictly taxonomic exhibit was one by the

Zoological Museum, Tring (Dr. K. Jordan) of fleas of the genus *Stephanocircus*, which are aberrant in structure and have a remarkable discontinuous distribution (S. America and Australia). Enormous geological upheavals are postulated to explain such examples and we must have considerable confidence in the high standards of our taxonomy if a flea is to raise a continent from the Antarctic Ocean.

Of all the orders of insects, the Lepidoptera have been the favourites of fellows of the Entomological Society, particularly amongst the large body of amateurs who have always formed its backbone. Butterflies and moths have a great propaganda-value in attracting students to entomology, and in many the interest is permanent. Some of the exhibits clearly indicated one source of this fascination Perhaps æsthetically the most striking of all the exhibits was the long series of the Large Copper butterfly, *Heodes dispar batavus*, shown by the Committee for the Protection of British Insects (Mr. H. M. Edelsten) The British form of this species became extinct before the middle of the last century, probably owing to human interference with the fens Its nearest representative is the geographical race living in the Dutch marshes, and this has been re-established at Wood Walton fen and certain other localities. Not only does this add a very beautiful insect to our fauna, but it provides an interesting experiment ; for the series of the butterfly preserved each year will show whether in its new surroundings the Dutch race shows any tendency to assume the characters of the native one. Professor E. B. Poulton showed two series of specimens illustrating well-known experiments on butterflies. The African species of *Precis* mostly fly in two forms, very different both in colour and in the shape of the wings. Most entomologists regarded these forms as distinct species, but Sir Guy Marshall was able to show by rearing broods from known parents and by subjecting the early stages to appropriate conditions, that the two apparent species were only seasonal forms of one. The other exhibit was of the gynandromorphs of *Papilio dardanus*, produced by Dr. G. L. van Someren by the application of mechanical shock to the newly formed pupa. This experiment not only indicated an entirely new method of investigating sex-determination, but also confirmed the view that the chromosomal mechanism of sex-inheritance in insects is by no means so irreversible as was once supposed. Although the sexual characters of an insect cannot be altered by castration or by transplantation of the gonads, Dr. van Someren's experiments as well as the data of parasitic castration show that the chromosomal balance can be upset.

Another subject for which the Lepidoptera provide very suitable material is the study of animal coloration, particularly in the special development of mimicry. Parallel series of models and mimics were shown by Professor Poulton, Dr. A. F. Rosa and Professor G. D. H. Carpenter. The last-named exhibitor showed a series of the forms of *Pseudacræa eurytus*, a butterfly whose variation his own studies have materially helped to elucidate. The polymorphism in this species is of a type which provides one of the best lines of evidence for the orthodox mimicry theory. The models have a variety of distinct colour-patterns, but in each geographical area a colour-form of the *Pseudacræa* is a close mimic. This combination of geographical with mimetic polymorphism is very difficult to explain on any but a selective basis.

After the Lepidoptera, the study of the natural history of insects has been, perhaps, the most popular branch of Entomology, as may be seen especially in the numerous observations recorded in the Proceedings of the Society. A number of exhibits worthily upheld this tradition. Mr. Hugh Main showed a unique collection of photographs illustrating the life-histories of various species. All observers of insects know that it is impossible in mere words to give a real impression of what is seen. Mr. Main's photographs, taken with the aid of his ingenious "subterraria," overcome this difficulty and preserve a life-like record of his numerous observations. The wonderful series illustrating the metamorphoses of the Tiger Beetle, *Cicendela campestris*, and of its parasite, *Methoca ichneumonides*, call for special mention. Mr. Ray Palmer, also, showed a fine series of photographs illustrating the transformation of the dragonfly, *Æschna Cyanea*. Mr. G. H. Mansbridge exhibited the larvæ of certain predacious Mycetophilid flies whose amazing habits he has recently discovered. These larvæ spin webs on the underside of logs or stones. In the webs are drops of a fluid which has been shown to be weak oxalic acid. Any small animal coming into contact with this fluid is soon paralysed, though the larva itself is immune. Dr. W. H. Thorpe showed specimens illustrating the life-history of the extraordinary fly, *Pantophthalmus tabaninus*, from Trinidad. The larva, which lives in rotten wood, has many points of morphological interest, particularly in the development of gills which appear to be of very small functional value. Two other exhibits demonstrated how a large association of insects may become adapted to highly specialised habitats. One was Dr. Hugh Scott's series of insects living in the sheathing leaf-bases of *Pandanus*, in the Seychelles, the other Mr. Donisthorpe's collection of insects living in ants' nests in Great Britain.

Morphology was represented by Mr. Maulik's specimens and illustrations of Hispine larvæ and Dr. Eltringham's models, drawings and microscopic preparations of scent-producing organs in insects. The Hispinæ are a sub-family of Chrysomelid beetles whose larvæ are peculiar in being leaf-miners. Their structure is highly modified and without direct observation it would often be impossible to guess their habits. Some of them, though really flattened for mining in leaves, closely resemble flattened beetle-larvæ of the family Helmidæ which are adapted to clinging on to rocks in torrents. Dr. Eltringham's contributions to the study of insect scent-organs are well-known and have for many years formed an important part of the Transactions of the Society His work was illustrated not only by actual specimens but also by beautiful drawings and models. When we find a complex scent-organ in the head of the Caddisfly, *Hydroptila*, of which the whole body is only a few millimetres long, the value of a large-scale model is obvious. It is a curious fact that scent-production is so often developed in the males. Probably all female insects have a scent for attracting the males, but the organ which produces it is a simple one, of small size and usually situated in some of the terminal abdominal segments In the males, on the other hand, the organs are highly complex, often more than one is present, and they may lie in almost any part of the body. The morphological study of these organs is in advance of our knowledge of their functional significance. It is known that in some species the male during courtship actually sprinkles a scented powder on the female and it is generally supposed that the scents act as aphrodisiacs. We are still ignorant, however, of why, in animals usually working with such nicely adjusted instincts, one sex should need such special attentions. Moreover, the occurrence of these structures is very sporadic and many species seem to be altogether without them.

The budding science of insect-physiology was scarcely represented, but the Imperial College of Science, Biological Field Station, showed Mr. Mansbridge's charts of the resistance of all stages of the Flour Moth, *Ephestia kühniella*, to high temperatures. The resistance fluctuates remarkably in the course of the life-history. The eggs, especially in the first few days of their incubation-period, are the most resistant, but the powers of the "resting larva" are not to be neglected. The sudden increase in resistance to an unfavourable environment shown by the late larva is of considerable economic importance and may perhaps be linked on to the somewhat similar observations on the cold-resistance of insects which have prepared themselves for hibernation.

In recent years the greatest expansion of Entomology has been on the applied side. Insects are so vitally important to man that it is surprising that he neglected their relations to him for so long. Doubtless the view that Nature is slowly changing and that the relations between animals do not follow a fixed, immutable law, has gradually accustomed Man to the idea of interfering with Nature, not only (as so often has happened with insects) to his own disadvantage, but also to attempt to bend it to his will. Most directly concerned with Man, was the exhibit of insects of medical importance shown by the London School of Hygiene and Tropical Medicine (Dr. V. B. Wigglesworth and others). In the old days, when human parasites were regarded as at the worst an unpleasant source of irritation, such an exhibit might have aroused no emotions other than amusement or disgust. Nowadays, however, when the rôle of these parasites as vectors of disease has been established, it is with more than passing interest that we meet some of our chief enemies face to face. Not many who have heard of sleeping-sickness or yellow-fever, have previously seen living specimens of the Tsetse Fly and of the *Stegomyia* Mosquito! The entomologist has another, less direct, interest in such insects, for many of them have recently proved to be easy animals to rear in artificial conditions and provide excellent material for experiment, as some of Dr. Wigglesworth's studies have shown.

Agricultural Entomology was represented, in the first place, by the exhibit of the Ministry of Agriculture, Plant Pathological Laboratory (Mr. J. C. F. Fryer). Excellent enlarged photographs of some of the more important insect-pests of agriculture in this country were accompanied by charts showing the abundance of the species in each of the last fifteen years. Such estimates of abundance are by no means easy to make, and their importance is greatly multiplied as the sequence of observations is extended. The Ministry has taken full advantage of its relative permanency and of its staff scattered over the country, in starting and maintaining this series of observations. Dr. D. S. Maclagan, in his charts showing the quantitative analysis of climate in relation to insect epidemics, illustrated how records, such as those of the Ministry of Agriculture, may be analysed so as to reveal some of the factors determining the numerical abundance of insects. The seasonal fluctuations in insect-numbers can be correlated with the meteorological data. In this work the investigator shows his skill in deciding which feature of the climatic record is significant. Sometimes it may be the temperature of the month preceding the outbreak, sometimes the rainfall in some critical month in the preceding year, or, again, it may be some unusual

combination of conditions. The climograph, in which the temperature is plotted against the rainfall or against some other measure of the evaporating power of the air, is an effective method of analysing the climate.

The enemies of agriculture in other countries found worthy representatives in the two cages of grasshoppers, the Desert and the Tropical Migratory Locusts, shown by the Imperial Institute of Entomology (Mr. B P. Uvarov). The dense crowd of active, voracious insects, which consumed their allotted food-supply during the course of the conversazione, gave a visitor some idea of what a real swarm would be like. Both the winged adults and the brightly coloured hoppers of the migratory phases were present. Mr. Uvarov's name is inseparably connected with the study of these creatures, for it was he who, in 1921, first put forward the phase-theory of the development of migratory locusts Before that date there were supposed to be two European species of locust, the solitary *L. danica* and the gregarious *L migratoria*. Uvarov showed by very careful taxonomic study that the supposed species intergraded with one another completely in some of their morphological characters, though their habits were quite distinct Finally, an invasion of the migratory form was followed up for several years in succession and it was found that their offspring became progressively more and more purely of the *danica*-form Uvarov was able to put forward tentatively the theory that the young hoppers of *danica* turn into *migratoria* when they grow up in a dense population, the marked changes in structure, physiology and habits depending on the stimulatory effect which the crowded hoppers have on one another. This theory has recently (1932) been brilliantly verified by the experiments of Fauré in South Africa, and it has been possible to enlarge the theory to include a large number of species of grasshoppers all over the world. Meanwhile, a promising approach to a rational control of the pest is opened out, for if the hoppers are never allowed to become sufficiently dense the destructive migratory phase will not develop. A practical illustration of this is seen in the Rocky Mountain Locust (*Melanoplus mexicanus spretus*) which was almost certainly the gregarious phase of *M. m. atlanis*. *M. spretus* became extinct about fifty years ago, almost certainly because the advance of cultivation made it impossible for the species to produce that phase. The solitary form is still common and occasionally very harmful, while the former prevalence of the gregarious phase was strikingly illustrated by the photographs exhibited by Rothamsted Experimental Station (Dr. C. B. Williams). At Mt. Cook, State of Washington, is a glacier the whole thickness

of which is striated with bands of frozen locusts. These belong to *M. spretus* and must have been laid down during the period when the swarming phase was still regularly produced. Presumably some local configuration of the mountains acted as a trap for the swarm, for no other records of this phenomenon on so large a scale are known.

A very different sort of trap was also exhibited by Dr. C. B. Williams, namely a light-trap for recording the abundance and flight-periods of nocturnal flying insects The use of the trap has already revealed a number of curious points, such as flights by unsuspected types of insects or the inhibition of flight by moonlight, and it is to be expected that the correlation of trap-records with meteorological data will much increase our knowledge of insect-ecology and of fluctuations in insect-numbers.

In no department of Economic Entomology has there been a more deliberate attempt to alter the inter-relations of animals in a direction favourable to man than in the recently developed method of biological control. Although the introduction of predatory and parasitic enemies of pests has long been discussed, and has been practised in the U.S.A. and in Hawaii for the last thirty years, it has lately gained greater prominence and the exhibit made by the Imperial Institute of Entomology, Farnham House Laboratory (Dr. W. R. Thompson and others), illustrated several aspects of the subject. To any ecologist a mere collection of all the parasites, hyperparasites and predators of any one species must be of surpassing interest. The large and varied fauna supported by those species which have been investigated and the rather discordant results of different experimental introductions, show how little we still know of the factors determining the abundance of animals. In the *Origin of Species*, Darwin showed how cats might influence the seeding of red clover; there are very few instances where our knowledge of such inter-relationships is much less empirical and on a more certain quantitative basis than in Darwin's day. Every attempt at biological control is an experiment which may help to elucidate this problem, and the breeding and identification of the parasites is leading to a great advance in insect taxonomy and bionomics. The control of noxious weeds by their appropriate insect-enemies is a more recent development of the same method. First applied successfully to *Lantana* in Hawaii, it is now recognised as an orthodox procedure, if carried out under sufficiently rigid conditions. Great care is required to ensure by adequate experiment that none of the insects chosen for introduction will attack economically important plants, even under the stress of hunger. The exhibits of the enemies of

Ragwort (*Senecio jacobæa*) and of St. John's Wort (*Hypericum*), which have become very injurious weeds in New Zealand and Australia, illustrated this branch of the subject.

Insects do not confine their attacks on our crops to plants still growing in the fields, but, after harvesting, other species take over the campaign and damage them in storage. Stored food-products are several stages nearer the finished article and damage to them is correspondingly of considerable financial importance. The ordinary householder who finds an occasional grub in his nuts or meal-worm in his porridge, has no conception of the vast hordes of insects which sometimes swarm in our docks and warehouses. The exhibit made by the Imperial College of Science, Biological Field Station (Mr. G. V. B Herford and others), enabled entomologists to see some of these pests in convincing abundance. Cultures of some fifteen of the more important species were shown swarming on the products to which they do most serious damage Actually almost all our foods are more or less acceptable to them, but like us they each have their preferences. In controlling these insects the methods of chemical warfare have proved very successful and Dr. A. B. P. Page showed apparatus and diagrams illustrating their employment. An essential consideration is that the gas employed as a fumigant should be evenly distributed throughout the warehouse, so that all the insects, even in the remotest crannies, may be destroyed. The most important aid in studying this problem has been gained by the use of a sampling apparatus devised by Dr. Page. This enables samples of gas to be withdrawn for analysis at any time during the fumigation and from any part of the warehouse. This has already shown what shape an ideal warehouse should have and has also proved that the way in which bags of food are stored has a material influence on the rate of diffusion. Moreover, the twenty-four hours during which it has been customary to shut up the gassed warehouse has been shown to be too long a period, since the concentration becomes negligible after ten hours.

Just as with the insects of medical importance, so with the stored-products pests, studies of primarily economic import have led to secondary results of considerable theoretical interest. The exhibit by Mrs. O. W. Richards of the factors affecting the multiplication of the Flour Moth and the Fig Moth are an example. An investigation of the best way to rear these animals in large numbers for experimental purposes has led to the discovery of a number of curious points in their physiology. At high temperatures the males become sterile, apparently owing to reduction in numbers and abnormality of the sperm. If the females of the Fig Moth are

given a drink of water every day, they live longer and lay twice as many eggs as females left thirsting. There appears to be a definite need of water to drink, since the same effect is not produced by maintaining a high relative humidity. Such studies, though arising directly out of economic entomology, promise to aid the solution of a number of difficult problems in the pure science.

If we compare the scope of modern entomology, as indicated by these exhibits, with the relatively narrow field covered by the first few volumes of the Society's Transactions, we cannot but wonder what may not be included under the same heading at the next centenary. It is a tantalising thought for an enthusiastic entomologist that none of us will be there to see it. But we may be sure that the Royal Entomological Society of London will play the same part in the advancement of this branch of Science in the next century as it has done in the last.

RECENT RESEARCH ON TIMBER

By W. P. K. FINDLAY, M.Sc., D.I.C.,
Forest Products Research Laboratory

It is only since the beginning of this century that timber, in common with some of the other important raw materials, has been the subject of special research in laboratories devoted to a study of its properties. The earlier work on wood was carried out, on the one hand, by botanists in connection with their general surveys of plant anatomy and with their studies concerning the rise of sap in trees and, on the other hand, by foresters interested in the quality of the material produced by their forests; while the physical properties of wood and the problems connected with its successful use as a constructional material were investigated by engineers. Thus the earlier literature on the subject is scattered throughout a wide range of publications, many of them somewhat obscure and difficult of access.

During the latter half of the nineteenth century a great deal of work was carried out on the timber of our common species of trees, at schools of forestry on the Continent, particularly in Germany. Collections of timber specimens were formed and their detailed anatomy described. The comprehensive study of timber itself as a subject independent of the sylvicultural side was developed at the beginning of this century in India and in the United States of America. In India a division of the Research Institute at Dehra Dun was devoted to the study of utilisation and the properties of the native timbers in relation to their uses were investigated; while in the United States a laboratory for the study of forest products was founded in 1910 at Madison in co-operation with the University of Wisconsin. Since that time other laboratories for the study of forest products (which in practice are mostly timber) have been founded in a number of countries including the United Kingdom, Canada, Australia and Finland, and considerable work on timber is also being carried out at some of the University schools of Forestry in the United Kingdom and America, as well as in Japan and other countries.

Forestry has been a subject which, until recently, was sadly

neglected in this country; the first forest officers for service in India were trained in France and Germany and the foundations of the Indian Forest Service were laid by two distinguished foreigners. Apart from Laslett (1875), Boulger (1902), some work by Marshall Ward, and a few isolated papers and catalogues by other workers, Great Britain had made, up to the outbreak of the Great War, but few contributions to our knowledge of the timbers of the world and their properties. About that time a department of timber technology was founded at the Imperial College of Science and Technology under Professor Groom, where work was carried on until his death in 1931. Amongst its many other duties the Imperial Institute in South Kensington found time to build up a fine collection of timber specimens and did some very useful pioneer work.

After the war the Forest Products Research Laboratory was established by the Department of Scientific and Industrial Research with headquarters at the Royal Aircraft Establishment at South Farnborough. Special buildings to house this laboratory were erected in 1927 at Princes Risborough in Buckinghamshire, but it was not until 1930 that extensions to the Laboratory enabled the whole of the Staff to be brought together under the same roof. It is the purpose of this article to describe some of the lines of work at the Princes Risborough Laboratory and to indicate how the results obtained are being applied in practice. The Staff of the Laboratory is divided into a number of sections, each of which deals with a different physical or biological side of the research, though, of course, most problems involve the co-operation of several sections.

Fundamental to the work of the whole Laboratory is a knowledge of the anatomical structure of wood and this study is undertaken by the section of Wood Structure, where detailed investigations both of timbers already well known commercially and of species as yet unknown to the timber trade, are in progress.

The structure of wood is subject to considerable variation according to the age of the tree and the position in the trunk from which the specimen was taken, as well as to the conditions under which the tree was grown. Many of the existing descriptions were based on inadequate material which was sometimes not typical of the species, and therefore are unreliable so that much of this descriptive work must be repeated. A collection of authenticated timber specimens taken from trees from which botanical material has been obtained is being built up for reference purposes.

The microscopic structure of wood is being studied in relation to its physical properties such as strength and liability to shrinkage on

drying, and, from the results so far obtained, it is hoped that it will eventually be possible to predict fairly accurately the properties of a timber from its structure alone. In the study of wood structure it is often necessary to determine the cell space ratio, *i.e.* the proportion of the total volume of the wood which is occupied by the cell walls, and as the measurement of this quantity by ordinary methods involves a great deal of labour a photo-electric photometer is being designed which measures the amount of light cut off by the cell walls in a stained transverse section; after correction has been made for the small amount of light passing through the stained cell walls, a rapid and reasonably accurate estimate of this ratio can be obtained.

In studying a new timber, with a view to its eventual uses, one of its most important aspects is its so-called "working qualities," *e.g.* the ease with which it can be sawn, riven, planed, etc., and its ability to take a finish or to be polished. These qualities are well enough known empirically as regards the timbers in common use, but they have never been defined or measured for new woods, and one of the difficulties met with in describing a new timber is to express them in terms that can be generally understood. The relation of the stresses undergone by the timber when in the machines to its physical properties is being examined by the Section of Timber Physics and an optical method intended to give some indication of the smoothness of a planed wooden surface has been designed.

The section of Timber Mechanics is concerned with the mechanical properties of timber, *viz.* bending strength, toughness, hardness, resistance to splitting, etc., and with such matters as the relationship between these properties and the structural characteristics of the timber, the influence of seasoning, the effect of processes and treatments and of conditions such as fungal attack upon the properties.

For the purpose of comparing timbers in regard to their mechanical qualities a standard scheme of testing is used in this and other Forest Products Laboratories, thus permitting the direct comparison of timbers tested in different parts of the world. The results of these tests enable one to ascertain the extent to which timbers may be substituted for one another and thus, for example in the case of Empire timbers, new to commerce, they indicate potential markets and uses.

Tests are also made upon full-size structural timbers, such as beams, joists and columns to determine their strength and the effect thereon of knots, cross-grain and other defects. The results of these tests will be used for the purpose of developing a system of grading structural timbers in terms of strength values, and they will

also serve as a basis for the preparation of tables of safe working stresses for the use of architects and others using timber in constructions. Full-scale mechanical tests are also proceeding on poles for transmission lines and on railway sleepers

Investigations carried out by this section on behalf of outside bodies include tests to determine the mechanical qualities of consignments of timber suspected to be defective and tests of various kinds of joints used in timber construction.

The amount of moisture held in a piece of wood is of fundamental importance in any consideration of its properties. When a tree is felled many of the cell spaces are filled with water which may be described as "free" moisture as distinct from the moisture held in the walls. Before timber can be used for anything except rough out-of-door work it must be seasoned, *i.e.* dried; in the past this has usually been accomplished by stacking the timber in an open place. This method, though effective, is slow and a large quantity of timber, representing a considerable amount of capital, must be kept in store; so accelerated methods of drying have been evolved whereby wood can be dried in a short time to a moisture content which it might not reach after a year or more drying in the open. The timber is stacked in kilns, where the temperature and humidity can be accurately controlled. The humidity, kept high at first to prevent unduly rapid drying of the surface with consequent cracking, is gradually lowered as the timber dries, while the temperature is correspondingly raised; moisture must not be removed more rapidly from the surface of the boards than it can move from the interior otherwise stresses which may permanently damage the timber will be set up.

Other subjects of enquiry at the Laboratory include a study of the way in which water is actually held by the cell walls as well as the more practical aspects of artificial drying such as kiln design and the schedules to be adopted when dealing with unknown or refractory timbers. It has been found that the shrunken condition, known as "collapse," which occurs in some woods during seasoning can be largely remedied by a short treatment with steam at 212° F. and this "reconditioning" treatment is being applied to a number of timbers, such as elm, which show distortion upon drying.

With a view to understanding the process of seasoning, the section of Timber Physics is studying the way in which moisture is held in the cell walls and how the moisture moves through the wood under a moisture-content gradient. Experiments indicate that practically the whole of the water in the cell walls is adsorbed so that, in drying, other forces than those due to capillary action

have to be overcome. Another line of research by this section in connection with seasoning is on the movement of heat in timber and its effect on the moisture gradient. As soon as the free water has evaporated from the cells and the walls begin to dry out, the timber begins to shrink and it becomes increasingly strong. Wood substance is colloidal in nature and absorbs or loses water according to the hygrometric condition of the atmosphere ; thus a certain amount of swelling and shrinking is continuously taking place. In order to minimise the amount of change of dimension that takes place in service, the timber, at manufacture, should contain roughly that moisture content, which it will eventually attain by reason of its environment when in use. In this connection a survey was made to determine the average moisture content of certain wooden articles in use, such as furniture in centrally heated rooms. From the figures obtained it is now possible to recommend the exact moisture content which wood should contain, when it is to be used for the manufacture of furniture.

The moisture content of wood is the all-important factor determining its resistance to decay ; wood which is perfectly dry is absolutely immune to the attacks of wood-destroying fungi, similarly wood which is waterlogged and contains no air is unaffected by decay, as the remains of sunken Roman galleys and the foundations of prehistoric lake dwellings testify. But when wood is damp it becomes liable to attack by a large number of different fungi, amongst which the most important are the higher Basidiomycetes. Woods vary greatly in their resistance to fungal decay according to their density and to their content of soluble extractives poisonous to the fungi. A series of laboratory tests upon the relative resistance to decay of various new woods from the Empire, as compared with that of well-known varieties, is being carried out by the Mycology Section. Small selected specimens are exposed to severe fungal infection in culture flasks and the loss in weight, due to decay, over a period of eight months gives a measure of the susceptibility of the timber to decay.

A study is being made of the physiology of these fungi and a large number of species are kept growing in culture, so that any fungus, isolated from material sent in for diagnosis, can be readily identified by comparison if it is similar to one of the already named cultures, isolated from a sporophore. This method has proved very useful for naming cultures which never develop fruit bodies ; many of the higher Basidiomycetes never, or only very rarely, form fertile sporophores in culture and often the hymeneal surface which does eventually develop is abnormal and wholly unlike the typical form.

While untreated timber in contact with the ground is liable to attack by a large number of different species, there are only one or two fungi of common occurrence in buildings and by far the most serious of these is *Merulius lacrymans*, the Dry Rot fungus, which is responsible every year for serious losses; a recent outbreak in a large housing estate near London causing damage to the value of £39,000.[1] This fungus, which is capable of penetrating through thick brick walls, can spread through a large building with amazing rapidity. A detailed study of its anatomy and physiology was carried out some years ago by Falck in Germany, who published a monograph on the species. Practical experiments upon the conditions favouring the outbreak of dry rot and means for its control are in progress at the Laboratory, where a special experimental building has been erected with a number of rooms constructed in various ways, some specially designed to favour the growth of the fungus. It has been found that the most important factor in the control of dry rot is the provision of adequate ventilation to the timber so that its moisture content is kept below the danger-point, *i.e.* below 20 per cent. of its dry weight.

Wherever wood is in contact with soil or otherwise kept continuously moist it should be treated with a wood preservative. In this country all railway sleepers and telegraph poles are thoroughly treated under pressure so that the preservative, coal tar creosote oil, is forced for some distance into the fibres of the wood. Surface treatment by dipping or painting is of little use for the permanent protection of timber to be used out-of-doors, for cracks soon develop which expose the untreated interior and the fungus, once having gained entry, rapidly decays every part except the treated skin. Creosote is a most efficient and (at the moment) cheap preservative, but it is unsuited for use in certain situations where there is objection to its smell or a risk of the oil creeping on to paint or " bleeding " through plaster. Research at the Laboratory includes the testing of proprietary and other special preservatives. This involves field tests in which treated samples of timber are placed in the ground and allowed to decay, the " life " of the treated as compared with that of the untreated specimens giving a measure of the preservative's value. Controlled laboratory tests are also carried out, in which small treated blocks of wood are placed in contact with actively growing cultures of wood-destroying fungi and the minimum concentration of the preservative in the wood, which will prevent all fungus growth, is determined. This so-called " toxic point " is used as a figure by which to compare the efficiency of preservatives. In

[1] *The Times*, April 5, 1933.

different countries the laboratory testing of preservatives has been carried out in a variety of different ways and the Laboratory is co-operating in an endeavour, initiated by Dr. Hermann von Schrenk in 1930 at a Conference in Berlin, to arrive at some standard method of testing which may be more or less universally adopted.

For very many years, the chief method of preserving timber has been by impregnation with antiseptics, and this practice has been very successful. There are, however, many problems to be solved. For instance, methods for treating timbers such as Douglas fir, which do not absorb preservatives readily, are being sought and a process known as "incising," in which small longitudinal slits are made in the wood before treatment, has been tested and proved greatly to increase the absorption of creosote. Another approach to the problem of preventing decay in timber may be possible when the chemical reactions involved in the decay processes are made clearer. The Section of Wood Chemistry is engaged among other things in a study of the action of various fungi on the major chemical constituents of wood, the cellulose, lignin, hemi-celluloses, etc. The rots of wood fall into two main groups, namely, the brown rots in which mainly the carbohydrates are attacked and the white rots in which all the constituents of the wood are depleted. It has been shown that the main reaction involved in the first type is hydrolysis which is closely similar in effect to the hydrolysis brought about by dilute mineral acids, while in the white rots an oxidising action takes place in addition to hydrolysis.

In the same way the nutrition of wood-inhabiting insects has been studied, and it has been shown that while some species, such as the *Lyctus* Powder-post Beetles, feed mainly on the cell contents, others, like the Death Watch Beetle, *Xestobium rufo-villosum*, feed mainly on the carbohydrates of the cell walls. The biology of the important economic species is being studied ; as the life-history of *Xestobium* occupies several years, perhaps sometimes as many as six, results on such species are of necessity slow in forthcoming.

The results of research are collected and their practical import considered by the Section of Utilisation which keeps in touch with the requirements of the timber trade and whose duty it is to discover what problems are in most urgent need of solution. Before a new timber can be successfully marketed a considerable amount of preparatory study is necessary ; the strength and durability of the timber, its behaviour on drying, its wood-working qualities, etc., must all be determined, before a fair judgment can be passed on the possible uses to which it may be put. Frequently with a new timber, difficulties arise in working which may lead to its falling into dis-

favour at first but can easily be overcome after a little research; for instance, difficulties in sawing a timber may sometimes be easily overcome by altering the teeth of the saw or the speed at which it is driven.

The Laboratory is assisting the development of the trade in timber from the Empire by investigating the properties of newly introduced timbers and by passing on to the producers in the Colonies and Dominions information regarding the requirements of the home trade. At present only a small fraction of our timber supply is drawn from Empire sources. As regards softwoods we shall probably never be quite independent of foreign supplies, though Canada is capable of supplying a very much higher percentage than she does at present, but in the case of hardwoods there is no reason why the Empire should not become entirely self-supporting.

My thanks are due to the Director of the Forest Products Research Laboratory for permission to publish this article and to my colleagues at the Laboratory for their assistance.

RECENT PROGRESS IN THE CHEMISTRY OF THE ŒSTRUS-PRODUCING HORMONES

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Introduction.—Few biochemical problems have within recent years been so full of interest to both the physiologist and the organic chemist as the fascinating problem of the constitution of the œstrus-producing hormone. In this review it would be out of place to deal at all fully with the events which led up to the physiological identification of the hormone, or with the vast number of researches which culminated a few years ago in its isolation in a state of chemical purity. These aspects of the problem have already been reviewed elsewhere (Allen and Doisy, 1927 [1]; Parkes, 1928, 1929 [2] [3]; Marrian, 1933 [4]). A brief account of some of the more important researches during these phases of the problem will however be necessary in order to make clear the significance of the more recent chemical work on the compounds in question.

The presence of an active substance in ovarian extracts which would cause the development of the symptoms typical of normal œstrus on administration to ovariectomised animals was first clearly shown by Marshall and Jolly in 1906 [5]. Later work by various authors showed that the hormone was definitely fat-like in its solubilities and that it possessed a high degree of thermostability. The development of a rapid and quantitative method of assay by Allen and Doisy (1923) [6] was the stimulus to a considerable amount of chemical research, but it was not until 1927, when Ascheim and Zondek [7] showed that the same or a similar hormone was present in large amounts in the urine of pregnant women, that any real progress was made. Shortly afterwards pure crystalline œstrogenic substances were isolated from pregnancy urine, independently and almost simultaneously by four different groups of workers (Doisy *et al.*; Butenandt; Dingemanse, Laqueur *et al.*; Marrian; cf. Marrian (1933) [4]).

From the work of these authors it was clear that at least two chemically distinct œstrogenic substances were present in human pregnancy urine, (*a*) a hydroxyketone, $C_{18}H_{22}O_2$ (called "*theelin*" by Doisy, "*the follicular hormone*" by Butenandt, and "*keto-hydroxyœstrin*" by Marrian), and (*b*) a triol, $C_{18}H_{24}O_3$ (called *trihydroxyœstrin* by Marrian, *theelol* by Doisy, and *the follicular hormone-hydrate* by Butenandt).

Butenandt and Hildebrandt (1931) [8] showed the important fact that trihydroxyœstrin could be converted into ketohydroxy-œstrin by dehydration *in vacuo* with potassium bisulphate. The presence of a phenolic hydroxyl group and an aromatic ring in both compounds was clear from the work of Butenandt, Doisy and the present writer. Since it was clear that in the conversion of the triol to the hydroxyketone, water was eliminated from the two non-acidic hydroxyl groups of the former, it was assumed with some justification that these two hydroxyl groups were attracted to adjacent carbon atoms.

Trihydroxyœstrin ("emmenin") has since been also isolated from human placenta by Collip, Browne and Thomson (1932) [9]. Its identity with pure urinary trihydroxyœstrin has been satisfactorily proved by Butenandt and Browne (1933) [10].

Other Naturally-occurring Œstrus-producing Substances.—In 1931 the present writer published results of several experiments, which appeared at the time to indicate that ketohydroxyœstrin when freshly prepared by distillation existed in an unstable and hyperactive form [11]. In later experiments it has not been found possible to repeat these results, and the writer is now of the opinion that the original high figures obtained for the activity of certain samples of ketohydroxyœstrin were the result of some error in the method of biological assay.

More recently a more well-founded claim has been put forward by Butenandt and Störmer (1932) [12] to have separated keto-hydroxyœstrin into two isomeric forms by repeated fractional crystallisation. The two forms, designated as the α and β hormones, are stated to differ in their melting points, optical rotations and physiological potencies. These authors have shown that when keto-hydroxyœstrin is prepared by distilling trihydroxyœstrin with potassium bisulphate, both isomers are produced. The yield of the β form appears to be increased by increasing the temperature of the distillation.

The number of known naturally occurring œstrus-producing substances has recently been increased considerably by the careful investigations carried out by various groups of workers on the

continent. Girard and his co-workers [13] [14] [15] have announced the isolation of three new œstrogenic hydroxyketones from mares' urine. Two of these, *equilin* and *hippulin*, are isomeric substances containing two less hydrogen atoms than ketohydroxyœstrin. The third compound, *equilenin*, contains four less hydrogen atoms than ketohydroxyœstrin and appears to contain a naphthalene nucleus in its molecule. A non-ketonic œstrogenic substance which is isomeric with ketohydroxyœstrin has been isolated from mares' urine by Schwenk and Hildebrandt (1932) [16] It differs markedly in melting point and optical rotation from ketohydroxyœstrin. The names *δ-follicular hormone* has been given to this new substance by its discoverers

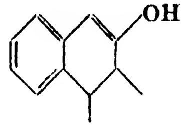
It seems extremely probable that many closely related œstrogenic substances remain still to be discovered in human and in mares' urine.

The Degree of Unsaturation of the Œstrins.—Until quite recently there was considerable difference of opinion concerning the important question of the degree of unsaturation of ketohydroxy- and trihydroxyœstrin. In one of his earlier papers Butenandt (1930) [17] showed that on catalytic hydrogenation the ketonic group of ketohydroxyœstrin was reduced to $=CH_2$, while six other hydrogen atoms were taken up, a product $C_{18}H_{30}O$ (m.p. 104°) being formed. This suggested the presence of only three double bonds in the molecule, which could be accounted for by the aromatic ring in the molecule, the presence of which was recognised at that time.

Thayer, Levin and Doisy (1931) [18] [19] determined the iodine values of both compounds and obtained figures in close agreement with those required for the addition of halogen to one double bond. These results suggested therefore that a fourth and non-aromatic double bond was present in both compounds.

In a later communication, Butenandt, Störmer and Westphal (1932) [20] also suggested that a fourth double bond was present in the œstrins. By a Clemmensen reduction of ketohydroxyœstrin they obtained a product $C_{18}H_{26}O$, which appeared to have no phenolic character. This was stated to differ from a second reduction product $C_{18}H_{24}O$ obtained by the Wolf method and which was phenolic. They were led to suggest therefore that the phenolic character of the hydroxyl group depended upon the presence of a fourth non-aromatic double linkage which, although resistant to catalytic hydrogenation, was reduced by Clemmensen's method. This theory was advanced in spite of the fact that the action of perbenzoic acid revealed the presence of only three double bonds.

They postulated the presence of the following grouping in the œstrins therefore:



The unsatisfactory nature of much of this evidence led the writer in collaboration with Mr. Haslewood to reinvestigate the whole question of the unsaturation of the œstrins (Marrian and Haslewood, 1932) [21]. They were unable to obtain constant iodine values with the œstrins themselves, presumably owing to substitution in the aromatic ring. With the methyl ethers of the two compounds, however, constant iodine values almost theoretical for one double bond were obtained. The results of Thayer, Levin and Doisy appeared to be confirmed therefore. When, however, the products were isolated from the iodine value determination mixtures, it was found that they contained not two atoms, but only one of halogen. It was clear, therefore, that the observed iodine values were due to the substitution of one halogen atom, and not to the addition of two at a double bond. There seemed to be no evidence, therefore, for the presence of a fourth double bond capable of adding an halogen.

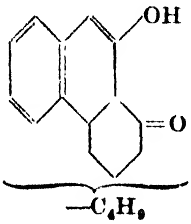
The Clemmensen reduction product of ketohydroxyœstrin was then prepared. It was found that it was, as stated by Butenandt, Störmer and Westphal, insoluble in aqueous alkali, but nevertheless it had marked phenolic properties. Furthermore, it analysed to $C_{18}H_{24}O$ rather than to $C_{18}H_{26}O$. There was no evidence, therefore, for the existence of the fourth double bond postulated by these authors, and it was therefore concluded that the œstrins contained no double bonds other than the three in the aromatic ring.

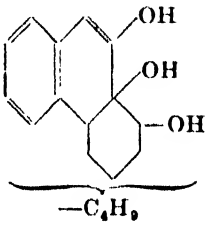
At about the same time, Butenandt himself reinvestigated the question (1932) [22]. More extensive hydrogenation experiments failed to reveal the presence of more than three double bonds, while molecular refraction measurements gave figures "compatible with a hormone formula containing three isolated double bonds or one benzene ring."

The Ring Structure of the Œstrins.—The first evidence on the structure of the œstrins was obtained by purely physical methods. Adam *et al.* (1932) [23] carried out an examination of unimolecular surface films of various derivatives of the two compounds and concluded from their measurements of the surface pressures and

surface potentials that the œstrins possessed condensed-ring carbon skeletons, either three-ring skeletons of the phenanthrene or anthracene type, or four-ring skeletons of the chrysene or naphthacene type. It was also concluded that the ketonic group in ketohydroxyœstrin and the two alcoholic hydroxyl groups in trihydroxyœstrin must be attached to a ring at one end of the molecule, while the phenolic hydroxyl must be situated near the other end. These conclusions were supported by Bernal (1932) [24], who carried out a crystallographic examination of the œstrins.

At the time of completion of this work it was still believed that the œstrins contained four double bonds (see p 71) It was necessary to suppose, therefore, that they were aliphatic substituted three-ring compounds, and accordingly Butenandt, Störmer and Westphal (1932) [20] were led to suggest structures I and II for ketohydroxy- and trihydroxyœstrin respectively.

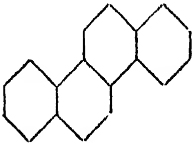
(I) 

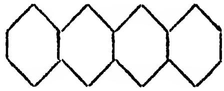
(II) 

The evidence advanced by these authors for the relative positions of the acidic hydroxyl and the ketonic group or the two alcoholic hydroxyl groups, was not at the time very convincing. It was furthermore directly opposed to the views of Adam *et al.* and of Bernal which are given above.

When it was definitely shown that the œstrins contained only three double bonds, it at once followed that they must possess four-ring carbon skeletons (Marrian and Haslewood, 1932 [21]; Butenandt, 1932 [22].

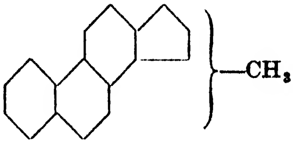
As has already been stated, the most probable four-ring skeletons on the basis of the surface film results were of the chrysene (III) and the naphthacene (IV) types.

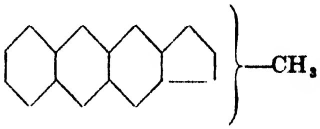
(III) 

(IV) 

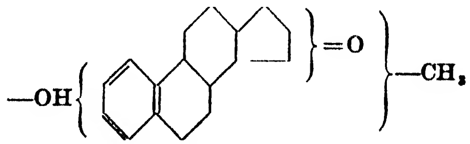
Marrian and Haslewood (1932) [21] obtained from trihydroxy-

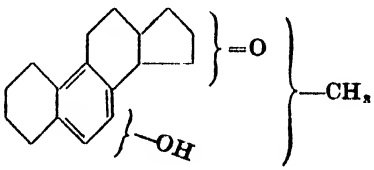
œstrin by a prolonged potash fusion, a phenolic dicarboxylic acid $C_{18}H_{22}O_5$, which was clearly formed by the opening of one ring between the two non-acidic hydroxyl groups. This acid on heating with acetic anhydride and distilling yielded the anhydride $C_{18}H_{20}O_4$, and not the cyclic ketone $C_{17}H_{20}O_2$. These results have been confirmed by MacCorquodale, Thayer and Doisy (1933) [25]. On the basis of the Blanc rule, this could be interpreted as evidence that the ring which had been opened was a five-membered rather than a six-membered one. The most probable carbon skeletons were therefore the following (V and VI):

(V) 

(VI) 

For reasons which were at the time not entirely justifiable, Marrian and Haslewood preferred a carbon skeleton of type V and suggested formulæ VII and VIII as probable alternatives for keto-hydroxyœstrin.

(VII) 

(VIII) 

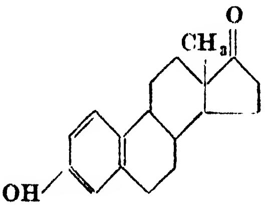
Later surface film work by Danielli *et al.* (1933) [26] clearly showed that the aromatic ring must be at one end of the molecule. Thus formula VII of the two proposed by Marrian and Haslewood appeared the most probable, although at the time a formula of the naphthacene type IV would have equally well been in keeping with the surface film results.

The Relationship of the Œstrins to the Sterol Group.—At about the same time as these developments were taking place in the œstrin field, the generally accepted views on the structure of the sterols and bile acids were undergoing drastic revision. Rosenheim and King (1932) [27, 28] suggested that a modified chrysene

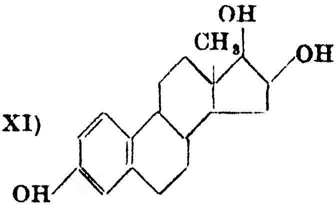
skeleton of type V would explain the chemical and physical behaviour of the sterols and bile acids considerably better than the previously accepted Windaus-Wieland formula. These views were adopted by both Windaus and Wieland.

With the adoption of this new formula for the sterols, it was immediately recognised that it was probable that the œstrins were themselves related to the sterols and bile acids, although there was no evidence at the time that such was the case. This led to a general preference for a formula of type VII rather than for one of the naphthacene type among workers interested in the subject (Butenandt, 1932 [29]; Cook *et al*, 1933 [30]; Robinson, 1933 [31]). Butenandt went so far as to place the substituent groupings in the œstrins by analogy with the Rosenheim-King-Windaus-Wieland formula for deoxycholic acid, and suggested formulæ X and XI for ketohydroxy- and trihydroxyœstrin respectively:

(X)



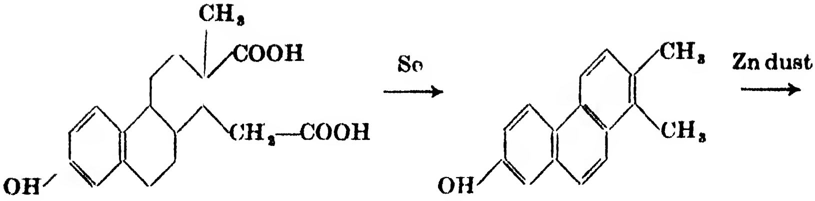
(XI)



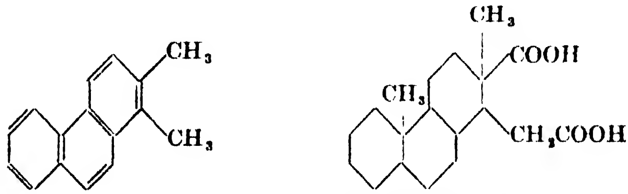
The publication of such speculative formulæ at a time when the only evidence in favour even of the carbon skeleton depended upon the supposed relationship of the œstrins to the sterols, was recently criticised by the writer (Marrian, 1933 [32]).

The fact that the œstrins are actually chemically related to the sterols has recently been proved by a series of brilliant researches by Butenandt, the results of which were recently communicated to the Chemical Society [32, 33].

The dicarboxylic acid obtained by potash fusion of trihydroxyœstrin on dehydrogenation with selenium yielded a dimethyl phenanthrol. This on distillation with zinc dust yielded a dimethylphenanthrene, which proved to be identical with 1:2-dimethylphenanthrene prepared synthetically by the method of Haworth (1932) [34]. Thus clear proof of the existence of a partially-reduced phenanthrene nucleus in the œstrin molecule has been obtained. The same dimethylphenanthrene was also obtained by selenium fusion of ætiobilianic acid, thus proving the chemical relationship between the œstrins and the sterol group. These reactions are shown diagrammatically below.



Dibasic acid from trihydroxyœstrin



aetiobilianic acid

The exact position of the hydroxyl group in ring 1 remains to be shown,[1] and also the exact points of attachment of the five-membered ring to ring 3 and the position of the ketonic group in it.

Synthetic Œstrus-producing Compounds.—One of the most remarkable recent developments in the whole field of the sex-hormones is the recent work of Cook and Dodds (1933) [30] [32] [35]. These workers have discovered the remarkable fact that a large number of synthetic condensed ring compounds show a well-marked œstrogenic potency on injection into ovariectomised rats. The synthetic compounds which are stated to have this action are as follows in the approximate order of decreasing œstrogenic potency: (1) 9:10-dihydroxy-9:10-di-n-butyl-9:10-dihydro-1:2:5:6-dibenzanthracene, (2) 1-keto-1:2:3:4-tetrahydrophenanthrene, (3) 5:6-cyclopenteno-1:2-benzanthracene; (4) 1:2-benzpyrene. In addition the remarkable fact has been found that neo-ergosterol, calciferol (vitamin D) and ergosterol also have some œstrogenic activity.

Two of these synthetic œstrus-producing compounds, namely 1:2-benzypyrene, and 5:6-cyclopenteno-1:2-benzanthracene are also powerful carcinogenic agents (Cook [36] [37]). As the authors comment [35], " it is very striking that both types of biological activity should be shown by one and the same compound."

It will be a matter of great interest to watch the further developments in this field. The availability in large quantities of these

[1] Butenandt states that proof of the position of the aromatic ring in the œstrin molecule is required. It has already been shown by Danielli *et al.* (1933) that ring 1 must be aromatic.

synthetic œstrogenic compounds may prove to be of considerable value clinically. It should at least be a great stimulus to further physiological and clinical research on the action of œstrogenic substances. It also seems possible that considerable light may be thrown on the whole problem of the development of malignant growths. Kennaway and Cook (1932) [38] have already made the suggestion that carcinogenic substances of the benzanthracene type might be produced in the body as a result of some abnormality in sterol metabolism. The fact that "the cell proliferation which characterises the œstrous state is in some respects reminiscent of the early stages of a malignant growth" (Cook and Dodds, 1933 [38], together with the fact that compounds having both carcinogenic and œstrogenic activity are now known, makes this suggestion seem a reasonable one. In view of the established relationship between the œstrins and the sterol group, it seems probable that the former may be produced from the latter by a process of dehydrogenation. Girard's compounds *equilin*, *hippulin* and *equilenin* probably represent further stages in such a hydrogenation process. It is not unreasonable to suppose that in certain circumstances the hydrogenation is pushed a step further with the production of carcinogenic compounds. It will be of interest to hear the result of the investigation now being undertaken by Cook and Dodds into the carcinogenic activity of 1:2-cyclopentenophenanthrene, which may be regarded as the basic aromatic hydrocarbon of both the œstrins and the sterols.

REFERENCES

1. Allen and Doisy, 1927, *Physiol. Rev.*, vii, 600.
2. Parkes, 1928, *Biol. Rev.*, iii, 208.
3. Parkes, 1929, *The Internal Secretions of the Ovary*. Longmans, Green & Co., Ltd.
4. Marrian, 1933, *Physiol. Revs.*, xiii, 185.
5. Marshall and Jolly, 1906, *Phil. Trans. Roy. Soc.*, B. cxcviii, 98.
6. Allen and Doisy, 1923, *Journ. Amer. Med. Assoc.*, lxxxi, 819.
7. Ascheim and Zondek, 1927, *Klin. Wochenschr.*, vi, 1322.
8. Butenandt and Hildebrandt, 1931, *Zeitschr. f. physiol. Chem.*, cxcix, 243.
9. Collip, Browne and Thomson, 1932, *Journ. Biol. Chem.*, xcvii, proc. xviii.
10. Butenandt and Browne, 1933, *Zeitschr. f. physiol. Chem.*, ccxvi, 49.
11. Marrian, 1931, *Chem. and Ind.*, l, 368.
12. Butenandt and Störmer, 1932, *Zeitschr. f. physiol. Chem.*, ccviii, 129.
13. Girard, Sandulesco, Fridenson and Rutgers, 1932, *C.R. l'Acad. Sci.*, cxciv, 1020.
14. Girard, Sandulesco, Fridenson and Rutgers, 1932, *C.R. l'Acad. Sci.*, cxcv, 981.

15. Sandulesco, Tchung and Girard, 1933, *C.R. l'Acad. Sci.*, cxcvi, 137.
16. Schwenk and Hildebrandt, 1902, *Naturwissen*, xxxv, 658.
17. Butenandt, 1930, *Zeitschr. f. physiol. Chem.*, xci, 140.
18. Thayer, Levin and Doisy, 1931, *Journ. Biol. Chem.*, xci, 655.
19. Thayer, Levin and Doisy, 1931, *Journ. Biol. Chem.*, xci, 791.
20. Butenandt, Störmer and Westphal, 1932, *Zeitschr. f. physiol. Chem.*, ccviii, 149.
21. Marrian and Haslewood, 1932, *Chem. and Ind.*, li, 277; *Lancet*, Aug. 6, cx, 2, 282.
22. Butenandt, 1932, *Nature*, cxxx, Aug. 13.
23. Adam, Danielli, Haslewood and Marrian, 1932, *Biochem. J.*, xxvi, 1233.
24. Bernal, 1932, *Chem. and Ind.*, li, 259.
25. MacCorquodale, Thayer and Doisy, 1933, *Journ. Biol. Chem.*, xcix, 327.
26. Danielli, Marrian and Haslewood, 1933, *Biochem. Journ.*, xxvii, 311.
27. Rosenheim and King, 1932, *Chem. and Ind.*, li, 464.
28. Rosenheim and King, 1932, *Chem. and Ind.*, li, 954.
29. Butenandt, 1932, *Zeitschr. f. angew. Chem.*, xlv, 655.
30. Cook, Dodds and Hewitt, 1933, *Nature*, cxxxi, 56.
31. Ramage and Robinson, 1933, *Nature*, cxxxi, 205.
32. Marrian, 1933, "Discussion on the Chemistry of Œstrin at the Chemical Society in London, March 16," *Chem. and Ind.*, lii, 289.
33. Butenandt, *Ber. deut. chem. Gesell.*, lxvi, 601.
34. Haworth, 1932, *Journ. Chem. Soc.*, 1126.
35. Cook and Dodds, 1933, *Nature*, cxxxi, 205.
36. Cook, 1931, *Journ. Chem. Soc.*, 2529.
37. Cook, Hewitt and Hilger, 1932, *Nature*, cxxx, 926.
38. Kennaway and Cook, 1932, *Chem. and Ind.*, li, 521.

RECENT ADVANCES IN SCIENCE

MATHEMATICS. By E. MAITLAND WRIGHT, M.A., D Phil., Christ Church, Oxford.

ADDITIVE THEORY OF NUMBERS.—The general problem of this theory is to determine whether every positive integer n is expressible in the form

$$n = g_1 + g_2 + \ldots\ldots + g_s,$$

where $g_1, g_2, \ldots g_s$ are to be chosen from some definite increasing sequence F of positive whole numbers $f_1, f_2, f_3, \ldots\ldots$, and s is to be less than some fixed S. The best-known example of this type of problem is Waring's Problem for k-th powers. Here the numbers g_i are to be chosen from the k-th powers of the natural numbers, that is, the sequence F is $1^k, 2^k, 3^k, \ldots\ldots$ Hilbert (1908) first proved that for every k there existed a number $S(k)$ such that every positive n could be expressed in the form

$$n = m_1{}^k + m_2{}^k + \ldots\ldots + m_s{}^k,$$

with $s \leq S(k)$. Other proofs were given by Hardy and Littlewood (1921) and by Vinogradoff (1924). The former authors found a definite upper bound for s in terms of k when n is sufficiently large, whereas Hilbert had only proved that $S(k)$ was finite.

Another problem of this type is that of expressing every integer greater than 1 as the sum of a certain number of primes, that is, the case in which the sequence F consists of the prime numbers 2, 3, 5, 7, 11,..... Goldbach conjectured that every even number greater than 2 could be expressed as the sum of 2 primes. If this is true, then every positive integer greater than 2 could be expressed as the sum of 3 or less primes, that is, if F is the sequence of primes and $n > 1$, then $S = 3$. Whether Goldbach's hypothesis is true is as yet unknown ; in fact, until recently, it had not been proved that a finite S exists in this case. However, in 1930, Schnirelmann proved that a finite S existed, in a paper in Russian. The proof was shortened by Landau (*Göttinger Nachrichten*, Math.-Phys. Klasse, 1930, 225–76). Landau remarks that his paper could have

been written a century earlier, and that he does not even use the calculus but only elementary properties of the logarithmic and exponential functions. This does not imply, of course, that the proof makes easy reading.

Schnirelmann has now published an account of his method for the general problem with very wide general conditions on the sequence F (*Mathematische Annalen*, **107** (1933), 649–90), treating Waring's Problem for k-th powers and the representation of numbers as sums of primes as particular cases.

Let $N(x)$ be the number of integers f_i of F which are less than or equal to x, and let $N(x)/x \geq \alpha > 0$ for all $x \geq 1$ Then the sequence F has "positive density." If we put $x = 1$, we see that every sequence with "positive density" must include the number 1. Schnirelmann proves that, when F has positive density, then S has a finite value.

Now let P_1 be the sequence

$$1, 2, 3, 5, 7, 11,$$

that is, the number 1 and the sequence of all primes. P_1 has not positive density, in fact, $N(x)/x$ behaves like $1/\log x$ as $x \to \infty$. Let P_t be the sequence of all numbers which can be expressed as the sum of t or less numbers of the sequence P_1, and $N_t(x)$ the number of members of P_t less than or equal to x. Then Schnirelmann shows that P_2 has positive density, that is, $N_2(x)/x \geq \alpha > 0$. Then it follows at once that every n is expressible as the sum of at most S_2 members of P_2, and hence as the sum of at most $2S_2$ members of P_1. From this it is quite simple to deduce that, provided $n > 1$, then n can be expressed as the sum of S or less primes (without the use of the number 1), where $S \leq 2S_2 + 1$. The value of S is as yet unknown; all that Schnirelmann has proved is that S is finite.

In his latest paper Schnirelmann considers a general sequence F, not necessarily of positive density. Let us take $f_1 = 1$. We say that F is a "basis of the natural numbers" if every n can be expressed as the sum of S or less members of F, where S is finite. Thus, every F with positive density is a basis of the natural numbers. Again any partial sequence chosen from F is said to be dense with respect to F if $N_1(x)/N(x) \geq \alpha > 0$ for all $x \geq 1$, where $N_1(x)$ is the number of members of the partial sequence less than or equal to x. If every dense partial sequence of F is a basis of the natural numbers, then F is said to be a continuous basis of the natural numbers.

Suppose that we have $f_i = O(i\phi(i))$ for a suitable increasing

function $\phi(i)$. Let $B(z)$ be the number of solutions of $f_i + f_j = z$. Then the condition

$$\sum_{z=1}^{x} B^2(z) = O(x^3/\phi^4(z))$$

is sufficient to show that the sequence F is a continuous basis of the natural numbers and that the sequence F_2, formed from all numbers which are expressible as the sum of two or less members of F, is of positive density. By means of these results Schnirelmann proves that a sequence formed of 1 and the prime numbers of the arithmetic progression

$$ax + b \; (x = 1, \; 2, \ldots \ldots),$$

where a and b have no common factor, forms a basis of the natural numbers.

Algebraic Theory of Partitions.—A linear partition of n is any set of positive natural numbers whose sum is n. We regard the parts as arranged in non-increasing order along a line. Thus, a partition of 8 is

4 3 1.

If $p(n)$ is the number of different partitions of n, we have

$$1 + \sum_{n=1}^{\infty} p(n)x^n = \prod_{l=1}^{\infty}(1 - x^l)^{-1}$$

This may be proved very simply by expanding each factor on the right in the form

$$1 + x^l + x^{2l} + x^{3l} + \ldots \ldots$$

Then it is easy to see that each partition of n gives rise to just one term x^n in the product. This result was regarded as " intuitive " by Euler.

Let us take any line partition of the integer n and arrange the parts in rows and columns, so that a non-increasing order of magnitude is in evidence in each row from left to right and in each column from top to bottom. Such an arrangement is termed a plane partition of n. Thus the particular plane partitions of 8 which are derived from the linear partition 4 3 1 are

431	43	41	4
	1	3	3
			1

The idea of a plane partition was introduced by Macmahon, who showed that, if $q(n)$ is the number of such partitions of n, then the generating function is

$$1 + \sum_{n=1}^{\infty} q(n)x^n = \prod_{l=1}^{\infty}(1 - x^l)^{-l}.$$

The truth of this result is not immediately apparent, as was the corresponding relation for linear partitions. Macmahon's proof is very lengthy and intricate.

Recently Chaundy (*Quart. J. of Math.*, **2** (1931), 234–40) found a much simpler algebraic method of determining the form of the generating function for $q(n)$. Finally (*Quart. J. of Maths.*, **3** (1932), 76–80), the same author has been able to construct an "intuitive" proof, that is a method by which we can correlate every plane partition of n with one of the terms x^n in the product

$$\prod_{l=1}^{\infty}(1 - x^l)^{-l}.$$

The algebraic method is actually simpler than the intuitive method, but it is interesting to see that such a correlation can be found.

It is worthy of notice that, if we consider "solid" partitions, the definition of which is an obvious generalisation of that of plane partitions, the generating function is not

$$\prod_{l=1}^{\infty}(1 - x^l)^{-\frac{1}{2}l(l+1)},$$

as we might expect by analogy. There appears to be no simple form for the generating function in this case.

Meromorphic Functions.—It is known that, if $f(x)$ is any given integral function, then there exists an integral function $g(x)$ such that

$$g(x + 1) - g(x) = f(x) \quad . \quad . \quad . \quad . \quad . \quad (1)$$

This statement is also true if the word "meromorphic" replaces the word "integral." J. M. Whittaker has proved recently (*Journal of the London Mathematical Society*, **8** (1933), 62–9) the two following theorems:

(i) If $f(x)$ is an integral function of order ρ, then there is an integral function $g(x)$ of order less than or equal to max $(1, \rho)$, satisfying (1).

(ii) If $f(x)$ is a meromorphic function of order ρ whose poles are all on the same side of the line $R(x) = d$, then there is a meromorphic function of order less than or equal to $\rho + 1$, satisfying (1).

General Transforms.—A paper with this title by G. N. Watson has just appeared in the *Proceedings of the London Mathematical Society*. It is known that for any arbitrary function $f(x)$, subject to appropriate general conditions, we have

$$f(x) = \frac{2}{\pi}\int_0^{\infty}\int_0^{\infty} \cos xy \cos yz\, f(z)\, dx\, dy.$$

This is Fourier's integral transform and may be expressed by saying that, if

$$g(x) = \sqrt{\frac{2}{\pi}}\int_0^\infty \cos xy\, f(y)dy,$$

then

$$f(x) = \sqrt{\frac{2}{\pi}}\int_0^\infty \cos xy\, g(y)dy.$$

A natural extension of the problem is to determine for what functions $\chi\ (xy)$ it is true that

$$f(x) = \frac{2}{\pi}\int_0^\infty \chi(xy)\chi(yz)f(z)dzdy,$$

with appropriate conditions on $f(x)$. Watson takes a slightly more complicated form of the transform integral and subjects $f(x)$ to the condition that its square shall be integrable in the Lebesgue sense over the interval 0 to ∞. Then he shows that the necessary and sufficient condition for the validity of the transform formula is that $\chi(y)/y$ shall have its square integrable in the Lebesgue sense over the range 0 to ∞, and that the formula

$$\int_0^\infty \frac{\chi(xy)\chi(yz)}{y^2}dy = \text{Min}(x,z)$$

is valid for all values of x and z between 0 and ∞.

Algebraic Fields.—An important and detailed paper by Hasse on "The Theory of Cyclic Algebras over an Algebraic Number Field" has appeared in the *Transactions of the American Mathematical Society*, **34** (1932), 171–214. In addition to new results, it contains the first account in English of much of the recent work of the German mathematicians in the theory of linear algebras and their arithmetics.

ASTRONOMY. By R. W. Wrigley, M.A., Royal Observatory, Edinburgh.

The Expansion of the Universe.—In *Zeitschrift für Astrophysik*, 1933, January, E. A. Milne offers a new kinematical explanation of the phenomenon of the expanding universe. The rate of expansion is accepted as being in accordance with Hubble's Law, founded on his observations at Mount Wilson, which connects the recessional velocities of the spiral nebulæ linearly with their distances, and gives a velocity of approximately 500 km. per sec. for 10^6 parsecs.

Actual velocities have already been measured up to 24,000 km. per sec., and it therefore seems as if some nebulæ must exist with speeds comparable with that of light. If this is correct, it is at variance with the theory that a frame of reference exists in which the velocities of all celestial objects are small compared with that of light, and removes one of the arguments which led to the conception of Einstein's spherical world.

According to Einstein, the expansion can be explained by assuming space to be curved and expanding, finite but unbounded. To this there are several serious objections. No reason has been formulated to show why the universe should be expanding rather than contracting or oscillating, and it has been found necessary to introduce a "cosmic time" which restores the ideas of absolute rest and of absolute velocity which were supposedly definitely abolished by the theory of relativity.

Milne attempts to show that the observed phenomena have nothing to do with gravitation, but are explicable in terms of flat infinite Euclidean space, the idea of curvature being definitely abandoned. His solution is a simple kinematical one, the universe being regarded as an unenclosed system with a central condensation. It is shown that a swarm of particles moving in straight lines, each with uniform velocity, in the absence of collisions or other interactions will tend to sort themselves out into spherical zones of gradually increasing recessional velocity as one goes outwards from the centre. The process is one of diffusion, the particles being supposed to have an infinite continuum in which to expand. Milne suggests this as a model of the universe, and imagines the spiral nebulæ as endowed with velocities exceeding the velocity of escape from the rest of the system, and therefore as describing paths practically indistinguishable from their rectilinear asymptotes. The universe of nebulæ occupies the interior of an expanding sphere whose centre is any nebula of the system chosen arbitrarily, and whose outer boundary expands with the velocity of light. The nebulæ, infinite in number, are strongly concentrated towards this expanding boundary, but the total light received in any direction is finite.

Only two postulates are found to be necessary. These are that the velocity of light is constant and that two observers in uniform relative motion have identical views of the universe. A mathematical treatment shows that these two postulates lead to a determination of the distribution of matter and motion in the universe, and imply Hubble's velocity-distance proportionality for the spiral nebulæ.

THE EXTERNAL GALAXIES.—In *Annals of Harvard College Observatory*, **88**, No. 2, Harlow Shapley and Adelaide Ames publish a survey of the external galaxies brighter than the thirteenth magnitude. This catalogue, which gives the positions and magnitudes of 1,249 objects, 224 being slightly fainter than magnitude 12·9, will be of great value for investigating the arrangement of these galaxies in space, the clustering of the nearer systems, and the presence of obscuring clouds of matter in low galactic latitudes. As all but thirteen of the objects are listed in the *N G.C.* and its supplements it is obvious that the latter is remarkably complete as regards number. The survey made by J A Hardcastle from his examination of the Franklin-Adams plates (*M.N R.A S* , **84**, 698) was less complete owing to the relatively small size of the plates, the proportion falling off for the fainter magnitudes

The present investigation therefore consisted primarily in identifying the extra galactic nebulæ already catalogued, and measuring their magnitudes and diameters. The photographs already made with the short focus patrol cameras of the Harvard northern and southern stations were used, and each object was measured on three plates. The magnitude estimations were based on the international standards by reference to stars in the Selected Areas, and, owing to the small scale of the photographs, the dimensions of most of the objects were sufficiently stellar for practical intercomparisons. The catalogue gives the number in the *N.G.C.*, the R.A. and Dec. for 1950, the galactic co-ordinates for 1900, the integrated photographic magnitude, the diameter in minutes of arc, and the type. Of the objects brighter than the thirteenth magnitude 700 show spiral structure, rather more than 200 are classed as spheroidal nebulæ, and the remainder are irregular or unclassified.

For a uniform distribution in space the number of observed nebulæ should increase by four times for each magnitude, and the following figures show that this proportion is approximately maintained :

between	mags.	10·0	and	10·9	there	are	50	nebulæ.
,,	,,	10·0	,,	11·9	,,	,,	221	,,
,,	,,	12·0	,,	12·9	,,	,,	734	,,

It therefore appears that these external galaxies are spread fairly uniformly throughout space. Their distribution in the sky is illustrated in four figures. These show a marked avoidance of low galactic latitudes, and a relative richness in the northern galactic hemisphere, in which there are just twice as many systems as there are in the southern. The emptiness in low latitudes can

be ascribed with some confidence to the presence of obscuring matter in and around our own galaxy, but there are some conspicuous vacant regions in both hemispheres which are not so readily explained. There appears to be no general concentration of external galaxies towards our own system. The whole region surveyed measures approximately 100 cubic mega-parsecs, in which the average density of matter is estimated at 10^{-30} grams per cubic centimetre, and one galaxy for each $6{\cdot}4 \times 10^{16}$ cubic parsecs.

In *Harvard Bulletin*, No. 889, Shapley emphasises the immense number of fainter galaxies which can be photographed with long exposures on fast plates A programme for covering the whole of the southern sky with the Bruce 24-inch telescope using exposures three hours in length is being carried through at Bloemfontein, and is estimated to take six years for completion. So far, 76,000 new galaxies have been discovered with a limiting magnitude of 18·2, and Shapley estimates the total number of such objects which may be found for the whole sky to be greater than 300,000, the majority lying in the region between 30,000,000 and 100,000,000 light years distant. The evidence in favour of the total number of these external galaxies being infinite is strengthening.

Our own Galaxy, its Size and Motion.—In the *Proceedings Nat. Acad. of Sciences, U.S.A.*, vol. XIX, No. 2, Joel Stebbins investigates the absorption and space reddening in the galaxy, the evidence being obtained from the colours of the globular clusters. The great distances of these clusters and their high intrinsic luminosities make them very suitable for testing the transparency of intervening space. The observational work was carried through at Mount Wilson, a photo-electric cell being attached to the 100-inch reflector, and the colour indices were determined by interposing filters in front of the cell. Calibration of the colour scale and a reference to a standard system of magnitudes were secured by the measurement of a star of known magnitude and spectrum in the neighbourhood of each cluster. It was found possible to obtain satisfactory colour indices for clusters and nebulæ ranging from 12·5 to 13·0 magnitude, and thus to include in the discussion all recognised globular clusters north of declination $-30°$. A definite reddening in low galactic latitudes was very obvious. Assuming the presence of a thin homogeneous layer of absorbing matter near the plane of the galaxy, a least squares solution from 42 equations gave for any cluster

$$\text{colour index} = -0{\cdot}081 + 0{\cdot}0237 \text{ cosec (galactic latitude)}.$$

The equivalent thickness of the absorbing layer is found by

Stebbins to be about twice the value derived by Trumpler from his study of open clusters (*Lick Bulletin*, No. 420). The discrepancy is probably due to the greater distance of the globular clusters, which are presumably sufficiently remote to show all the absorption present in the whole galactic system. If Stebbins' estimate is correct, considerable reductions will be necessary in Shapley's measures of the distances of the globular clusters, for these were made on the assumption that space was transparent. As these clusters are situated round the outer fringe of the galaxy the estimated size of the latter is correspondingly reduced. Stebbins calculates that its diameter is 30,000 parsecs instead of 80,000, the sun being 10,000 parsecs distant from its centre. These new estimates not only make its general form more symmetrical and more condensed round its centre, but they make it much more comparable in size with other external systems of similar form. Hitherto it has been regarded as a super-galaxy, a continent surrounded by islands, exceptional in size if not in structure. Some centuries ago the idea that our own galaxy occupied a prominent and privileged place in the universe would have been accepted as only natural and proper, but now the pendulum has swung far in the other direction, and present-day preference is to regard it as an insignificant unit among an unnumbered host of similar companions. Stebbins' estimated radius of 15,000 parsecs is only three times the radius of the Andromeda nebula if we assume the latter to include the objects recently found by Hubble outside the actual star clouds and identified by him as globular clusters (*Mount Wilson Contribution*, No. 452).

In addition to this similarity in size a similarity in mass between the two systems is demonstrated by J. H. Oort in *B.A.N.*, No. 238. From dynamical and statistical consideration he estimates the total mass of our galactic system, including stars to visual absolute magnitude 13·5, as 0·038 times the solar mass for each cubic parsec of space. This result is of the same order as Hubble's value for the Andromeda nebula (*Mount Wilson Contribution*, No. 376).

In the *Lick Observatory Bulletin*, No. 488, Phyllis Hayford describes her attempt to determine the Rotation of the Galaxy from measures of the radial velocities of the open galactic clusters. Other investigators have used the proper motions and radial velocities of various different types and groups of stars as well as of the planetary nebulæ, but a study of the open clusters appears to offer special advantages both on account of their great distances and galactic concentration, and also because their parallaxes have already been determined by R. J. Trumpler. A one prism spectro-

graph attached to the 36-inch refractor was used to secure the plates, and the comparison spectra were hydrogen, helium, and argon. Measurements were obtained for 161 stars, chiefly of the high temperature classes O5 to B5, selected out of 29 clusters lying within 10 degrees of the galactic plane, and well distributed between longitudes 311° and 206°. From these measures velocities were adopted for 25 clusters, ranging in distance from 940 to 3,360 parsecs, and the galactic rotation was then obtained by a method of harmonic analysis specially developed by Miss Hayford. The centre of the galactic rotation is found to lie in longitude 333°, in approximately the same position as the centre of the globular clusters, and 1,800 parsecs distant from the sun. This direction is in good agreement with previous determinations, but the distance from the sun is much less than that derived by Oort from dynamical considerations.

All such researches into the motions of the stars composing the galaxy would be greatly facilitated if a galactic system of co-ordinates were employed instead of the usual Right Ascension and Declination The advantages of a reference to a natural and invariable plane, by which the difficulties inherent in a system depending on an equator and equinox which are continually changing, was stressed over twenty years ago by the late R. T. A. Innes, who proposed that in all stellar catalogues reductions should be made to galactic longitude and latitude. This suggestion, however, proved too ideal to be adopted, and equatorial co-ordinates have been retained. Various tables and graphs have been published from time to time to aid in the necessary transformation to galactic co-ordinates, and those by P. Emanuelli (*Pub. Spec Vaticana*, 1929) are very useful for statistical investigations in which an accuracy of one-tenth of a degree is all that is required. For more accurate work a new set of tables have been prepared by John Ohlsson, and are published as No. 3 of the *Annals of the Observatory of Lund*. Obviously a plane of symmetry for all the objects of various types contained in the galaxy can never be defined with absolute precision; the plane adopted by Ohlsson is the one used at Harvard and elsewhere for many years (galactic pole R.A. 12 h. 40 m., Dec. + 28° (1900·0)), but reduction tables are provided if a change in position is desirable. The galactic longitudes are measured from the ascending node of the adopted galactic plane on the equator at the epoch 1900·0, and are therefore free from precession, while it is an easy matter to change to any other zero reference point such as α Cygni, the solar apex, or the direction of the centre of the galaxy itself. The tables are well printed and handy to use, and assist either in the conversion of equatorial into galactic co-ordinates or vice versa,

while proper motions are readily transformed from one system to the other by means of a tabulated parallactic angle.

Stellar Radial Velocities.—Vol. XVIII of the *Publications of the Lick Observatory* consists of a "General Catalogue of the Radial Velocities of Stars, Nebulæ, and Clusters," by J. H. Moore. Earlier lists were published by J. Voûte in 1921 and 1928, but so rapid has been the accumulation of new data in the last few years that a new comprehensive catalogue had become an urgent necessity. Dr. Moore has included all radial velocities published prior to January 1, 1932, and the stars in his catalogue number 6,739, the bulk of which were observed at Lick or its branch in Chile. For each star there is given its number, visual magnitude, and spectral class, all taken from the Henry Draper Catalogue, the spectral class as re-estimated by the observatory responsible for the observation, the published radial velocity, the dispersion of the spectrograph employed, the relative weights assigned to different determinations, and the value finally adopted with its probable error. A careful examination was made of the systematic differences already known to exist between velocities determined at different observatories. The Lick system was found to be in close agreement with the mean of the whole number, and it was therefore adopted as the standard of reference. In his introduction Dr. Moore gives a table of the systematic corrections which were applied to the radial velocities for different spectral types of stars for each observatory; much the largest is needed by the observations made at Ottawa between 1920 and 1922, in which case it reaches + 9·4 km per sec., while the next in size is - 2·7 km. per sec. applied to the M star observations made at Bonn

In addition, Moore includes the radial velocities of 133 gaseous nebulæ, of 18 globular clusters, and of 90 extra galactic nebulæ. The first group were observed almost entirely at Lick, and the others at the Lowell and Mount Wilson observatories. The largest velocity listed is the 19,700 km. per sec. of Leo cluster No. 1, the displacements observed in the spectral lines being assumed to be caused entirely by relative motion. This velocity is no longer the highest known, for Humason has since found a value of + 24,000 km. per sec. for the two brightest members of the Gemini cluster of nebulæ, and has under consideration spectrograms of fainter objects for which still larger red-shifts are suggested (*Mount Wilson Annual Report*, 1932).

Two other volumes dealing with radial velocities have been issued as Nos. 1 and 2 of vol. V of the *Publications of the Dominion Astrophysical Observatory*. In the first, J. S. Plaskett and J. A.

Pearce give a list of the radial velocities of 523 O and B type stars, obtained at Victoria between 1923 and 1929 with a one prism spectrograph attached to the 72 inch reflector. In all, 2,679 spectra were measured, with an average of 9 lines in each The stars, whose velocities were determined for the first time, range from B0 to B5 in type, are all brighter than visual magnitude 7 50, and are situated to the north of declination $-11°$. The new spectroscopic binary stars discovered in this investigation number 117, and it is estimated that 26 per cent. of the fainter B type stars belong to this class. The second volume, a catalogue of all the radial velocities so far observed for stars of types O to B5, gives values for 1,010 stars derived from 16,069 stellar spectra. These include 319 spectroscopic binaries of which 80 have had their orbital elements determined, and the percentage of this class among the whole group of O and B type stars comes out at 32. The probable errors of the velocities finally adopted show rather wide differences, 33 per cent. lying between 0 and 0·9 km per sec. and 12 per cent. exceeding 2·9 km. per sec., the latter group averaging 4·03 km. per sec. It is clear that there is considerable variation in the quality of the spectra secured: systematic differences between results obtained at the principal observatories are found to be satisfactorily small. Upwards of 70 stars hitherto classed as spectroscopic binaries are now withdrawn from that class, the apparent variation in velocity being ascribed to errors in observation or measurement.

A Massive Star.—The number of stars whose masses have been directly determined is still comparatively small, but it appears that the great majority lie between one-fifth and five times that of the sun The most massive stars are of type O and the least are the M dwarfs, a steady decrease being shown through classes B, A, F and G of the main sequence. In *Monthly Notices, R.A.S.*, **92,** No. 9, J. A. Pearce describes an interesting binary system, H.D. 698, the combined mass of which exceeds that of any other yet known. This distinction has hitherto been held by the system H.D. 47129, of spectral type O8, investigated by Plaskett, in which the minimum combined mass is 139 times that of the sun. Pearce finds that H.D. 698 is decidedly more massive, the minimum combined mass being 158, and the components 113 and 45 times the sun. The parallax is estimated at 1,220 parsecs and the absolute magnitude of the system as $-3·4$. The luminosity is therefore small in comparison with the enormous mass. The spectra of the two components are of types B9 and B5, and the period of revolution is 55·9 days. The system H.D. 1337, of spectral type O8 and combined mass 70 times the sun, is now third in order.

H.D. 698 is the first star of type later than B5 in which it has been possible to detect the stationary K line due to the presence of ionised calcium in interstellar space. This line has been generally observed in early type spectra, but for other stars it has been hidden by the intensity of the stellar calcium lines, and the later the type the more difficult becomes its detection It is necessary for the star to be very distant in order to provide sufficiently strong absorption by the interstellar calcium, and for it to have a large radial velocity so that its own K line may appear separate and distinct. These conditions are realised in H.D. 698, and Pearce has found that, for a few days of the 56-day period when the two components possess maximum relative velocity, the single calcium line divides into three, two of which represent the orbital oscillations of the binary and the third sharper one being quite stationary. This provides further evidence in favour of Eddington's theory of a uniform distribution of diffuse matter in interstellar space.

PHYSICS. By L F. Bates, Ph.D., D.Sc., F.Inst.P., University College, London.

Is there a Positive Electron ?—Nearly forty years ago the electron, a negatively charged particle with a mass approximately one-two-thousandth part of the mass of a hydrogen atom, was discovered. In recent months the neutron, an uncharged particle with a mass very approximately that of a hydrogen atom, was discovered. Now, it is suggested that a positive electron, a positively charged particle with a mass of the same order as that of the negative electron, exists.

This suggestion arises from a consideration of recent experiments on cosmic radiation, the highly penetrating radiation which appears to reach us from the depths of space. Early experiments on this radiation were performed almost exclusively with the aid of the cosmic-ray electroscope, a sensitive electroscope heavily protected by jackets of lead. They had their origin in the observation, made at the close of last century, that however much lead is wrapped around a sensitive electroscope, some residual loss of charge is always recorded, after the necessary allowance is made for loss of charge by electrical leakage across the insulating supports and so forth.

A modern cosmic ray electroscope, in its simplest form, consists of a fine stretched wire, carefully insulated and mounted near an uninsulated plate inside a thick lead case, usually containing argon under high pressure. A self-recording form has been extensively used by Millikan and his collaborators; such electroscopes have

been sent up in small balloons to record the amount of penetrating radiation in the upper atmosphere. They have been sunk deep in the high-altitude snow-fed lakes of the Andes, where the pure water, free from radioactive contamination, acted as a layer of absorbing material of adjustable thickness and thus permitted the determination of the absorption coefficient of water for cosmic radiation from measurements of the residual ionisation at known depths. Regener (*Zeit. für Phys*, **74**, 433, 1932) has also used a very neat self-recording electroscope for experiments in the depths of the Bodensee.

A portable apparatus for cosmic ray measurements is described by A. H. Compton (*Phys Rev.*, **43**, 387, 1933) It consists of a 10 cm. spherical steel ionisation chamber filled with argon at thirty atmospheres pressure, connected to a Lindemann electrometer, and shielded with 2·5 cm of bronze and 5·0 cm. of lead The apparatus is calibrated by comparing the ionisation current due to the cosmic rays with that produced by a standard radium source placed at a known distance from the chamber

With such portable instruments, measurements of the intensity of cosmic radiation at sea-level have been made at specified times of the day in many parts of the world A preliminary account of measurements made by eight different expeditions at about seventy representative points on the earth's surface is given by Compton (loc. cit.). This survey has shown that the intensity of cosmic radiation at sea-level becomes greater as the distance from the equator increases. It is most interesting that the results so far obtained may be satisfactorily expressed as a function of the geomagnetic dip alone, we shall return to this point later. As Gunn (*Phys. Rev.*, **41**, 683, 1932) has pointed out, this dependence on dip should be accompanied by pronounced diurnal changes in the intensity of the radiation if it is of a corpuscular nature Diurnal variations have, of course, been recorded, but a sufficiently detailed survey is not yet available. We may add that the survey reported upon by Compton, appears to confirm the observations made by Piccard in his recent balloon ascents (*Nature*, **130**, 570, 1932 and *Naturwiss.*, **20**, 592, 1932), and to fix the ionisation produced by cosmic radiation at two hundred ions per c.c. per sec. at 16,000 metres above sea-level. The ionisation at sea-level is a little less than two ions per c.c. per sec.

We see, then, that whilst the electroscope has given, and will continue to give very valuable information, this method of attacking the problems of cosmic radiation is relatively an indirect one, and, in general, measures only the average ionisation produced by the

radiation in a known interval of time To obtain detailed information of the individual processes of cosmic ray ionisation the electroscope is replaced by a Geiger-Müller counter or an expansion chamber. In its simplest form the Geiger-Müller counter consists of a metal cylinder surrounding a coaxial stretched wire. The whole is enclosed in a glass tube filled with air at about 10 cm. pressure. A negative potential of about 1,500 volts is applied to the metal cylinder. When an electron is produced by cosmic radiation inside the tube, it is driven so swiftly towards the wire that it produces ionisation by collision, and thus sets in motion a discharge which can be recorded by a valve amplifier. A suitable grid leak attached to the latter permits the discharge to stop and the counter to recover, so that successive ionisations may be recorded by loud-speaker or recording attachments. This instrument is particularly suitable for the investigation of the directional properties of cosmic radiation. For this purpose, three such counters may be arranged close together in line and so connected that a signal is only recorded when all three are simultaneously discharged, for, whatever their nature, the velocity of the radiations is very great. This is the basis of the arrangement used by Johnson (*Journ. Franklin Inst.*, **214**, 665, 1932), which will undoubtedly provide much interesting data. So far the angular distribution of the radiation has been investigated for relatively few stations. The curve of intensity with angle with the vertical so obtained is shaped like the curve obtained by plotting the magnetic field at points along the axis of a coil carrying a current with distance from the centre of the coil. The intensity in the horizontal direction is about two per cent of that in the vertical direction.

We see, then, that the counter gives us more information about the individual ionisations and the directional properties of the radiation than does the electroscope, but it does not tell us exactly how the ionisation occurs. To obtain such information we must turn to another method of investigation first employed by Skobelzyn (*Zeit. für Phys.*, **43**, 354, 1927), the method of the Wilson cloud chamber, which has given such spectacular results in the case of experiments on α-rays. It is known that about a dozen quanta of penetrating radiation pass through the body of a man of average size per second. Consequently, if an automatic Wilson expansion chamber is kept working continuously, the tracks associated with cosmic rays which have passed through the chamber will occasionally be rendered visible, by the condensation of water vapour upon the ions along the tracks, and will be photographed. Obviously this procedure is relatively inefficient, and, actually, taking the

photographs corresponding to some three thousand expansions, C. D. Anderson (*Phys. Rev.*, **41**, 405, 1932) obtained only sixty-two records of tracks due to cosmic rays, which, for brevity, we will call cosmic ray tracks.

In Anderson's apparatus the piston of the expansion chamber was horizontal, and it operated in a magnetic field of 21,000 gauss. This field was maintained by an electromagnet and photographs were taken through a hole in the pole-pieces parallel to the lines of force. It was assumed that the radiation producing the tracks passed downwards through the chamber. The recorded tracks were all curved by the magnetic field, and on the above assumption, it was concluded that some tracks were produced by positively charged particles and some by negatively charged particles. From the ionisation along the tracks attributed to positively charged particles, Anderson concluded that these particles were mainly protons. Of fifty-five of his photographs of cosmic ray tracks, seven showed double tracks and one showed three tracks. The energies of the particles producing the tracks ranged from about 10^6 to 10^9 electron volts.

The enormous energies possessed by these particles consequently render it imperative to use extremely powerful magnetic fields if the tracks are to be bent sufficiently to permit the accurate measurement of their curvatures, required for the evaluation of the masses of the particles. Such fields may be produced by electromagnets, but the iron pole-pieces obscure the view of the expansion chamber, and in highly accurate work, and, more particularly, when stereoscopic pictures are required, their use must be avoided. For this reason Kunze (*Zeit. für Phys.*, **79**, 203, 1932; **80**, 559, 1933) has produced a field of 18,000 gauss by means of an iron-free coil supplied with a current of one thousand amperes, corresponding to a power of five hundred kilowatts, provided at night inside the power station of the Rostock town electricity supply. Such a huge current could only be maintained in the coil for about fifty seconds, and as each expansion of the chamber occupied three seconds, only eighteen records could be obtained before the coil was too hot for further work. As the coil then took a whole day to cool, only eighteen records could be made per night; of these, of course, only few would contain records of tracks. Incidentally, it may be mentioned that a magnetic field so produced has a very considerable stray field, and all loose pieces of iron must be carefully removed from the room in which the coil is placed; otherwise they will be sent hurtling through the air into the middle of the coil, when the current is switched on.

On seventy-five plates, Kunze obtained records of sixty-one single tracks, thirteen double tracks and one triple track. Assuming that the radiation passed vertically downwards through his expansion chamber, the single track records show the presence of rather more positively charged particles than negatively charged ones, and Kunze considered the former to be protons. The maximum particle energy which he definitely measured corresponded to nearly $2 \cdot 7 \times 10^9$ electron volts, but other particles appeared to possess energies greater than this, unfortunately, their tracks could not be measured with accuracy. Kunze plotted the number of particles with energies within specified limits against the average energy between these limits and he obtained a curve which indicated no upper limit to the energy of the particles, although the number of particles with a given energy decreases rapidly with increase in the energy. Kunze will later publish an account of the properties of his multiple track records.

However, electrons and protons are not the sole producers of tracks in these expansion chamber experiments. For, Anderson (*Science*, **76**, 238, 1932) showed that one track could not be attributed to a proton, assuming as before that the cosmic radiation passed downwards through his chamber. The energy of a proton giving rise to the curved path described in his magnetic field would have had to be three hundred thousand volts. Yet such a proton would only have a range of about 5 m.m. in the air in the chamber, whereas the uniformly curved track was over 5 cm. long. Consequently, the track was attributed to a particle carrying a positive charge but having a mass of the same order of magnitude as that normally possessed by a free negative electron. This was the first suggestion, or, more accurately, the first experimental indication of the existence of a positive electron. Anderson (*Phys. Rev.*, **43**, 491, 1933) has since identified fifteen tracks out of a group of thirteen hundred photographs of cosmic ray tracks as due to these positive electrons, and he considers, on the basis of the ionisation along the tracks, that their charge is probably exactly equal to that of the proton, so that, if this charge is correct, the curvature and ionisation of the tracks require that the mass shall be less than twenty times the electron mass.

So far we have not specially emphasised a point of great interest, namely, the frequent occurrence of multiple tracks in the expansion chamber experiments. Such occurrences might have been predicted from the occasional bursts of ionisation recorded by the electroscope method, when over a million ions may suddenly be produced in the ionisation chamber. Hoffmann and Pforte (*Phys. Zeit.*, **31**, 347,

1930) first recorded such bursts, which Steinke and Schindler (*Zeit. für Phys.*, **75**, 115, 1932) have further investigated. These bursts must be due to heavy charged particles, as the latter produce ions much more prolifically per cm. of path in the ionisation chamber than light particles.

There appears to be little doubt as to the origin of the multiple tracks. Thus Anderson (*Phys. Rev.*, **43**, 368, 1933) describes a photograph which shows a group of twelve tracks, whose appearance, *i.e.* blurring of the track of condensed water vapour droplets by diffusion, showed that they were simultaneously produced. Seven of the tracks clearly originated from a common point in the upper portion of the expansion chamber, probably in its wall. The remaining five tracks, while not appearing to come from this point, do, however, come from the same part of the chamber. The bulk of the tracks appear to be due to electrons.

The most complete information of these bursts of particles has so far been obtained by Blackett and Occhialini (*Proc. Roy. Soc.*, **139**, 699, 1933). They owe their success to a particularly efficient combination of the counter and the expansion chamber. Two counters were mounted on a vertical line and between them was placed an expansion chamber. The counters were so connected that, if both were (practically) simultaneously discharged by the passage of a cosmic ray vertically downwards, then the expansion chamber was set in action and a pair of photographs of the tracks produced by the cosmic ray was taken. The two photographs did not form a stereoscopic pair, but facilitated a reconstruction of the tracks in the form of a model of thin wires. The mechanism of the expansion chamber was so nicely adjusted that the expansion was completed in about one-hundredth of a second after the discharge of the counters. Consequently, with this arrangement photographic plates were exposed, when, and only when, there were cosmic ray tracks waiting to be photographed. The expansion chamber was situated in a magnetic field of about 3,000 gauss produced by a current of two hundred amperes flowing in a water-cooled iron-free coil.

Some five hundred exposures were successfully made in this way and the photographs show that the variety and complexity of the multiple tracks is most extraordinary. Some of the photographs show more than twenty separate tracks, many of which seem to originate in a common point, usually situated in the material of the coil or the side of the chamber. Again, on the assumption that the particles are passing downwards from such a common point—and we cannot seriously imagine that the tracks converge

to a common point—some of the tracks are due to particles with a positive charge associated with a mass of the same order of magnitude as that of the electron. Anderson has suggested the name "*positron*" for these particles. There is no doubt that their range, ionisation, and track curvature in a magnetic field all indicate that these positive particles are not protons, but in the present state of our knowledge it is wise to state that we have evidence, but not proof, of the existence of a positive electron. They appear to be produced by the artificial disintegration of a nucleus when a primary cosmic ray strikes it.

Blackett and Occhialini computed that over a thousand single-track cosmic rays must have passed through their chamber for every shower recorded. The complicated tracks clearly arose from several distinct processes. Sometimes a swift particle merely ejected one or more negative electrons from a nucleus. In other cases, many particles were simultaneously ejected, and positive and negative electrons appeared to predominate in the showers, their numbers being about equal. Again, the showers appeared to be accompanied by non-ionising particles or photons, for tracks often appeared on the plates showing showers some distance from the main group and unaccompanied by the track of an incident particle.

Now, such showers emerged from the relatively light atomic nuclei of air, glass, aluminium and copper, in which it is now considered that no free electrons exist (c f Heisenberg, *Zeit für Phys*, **77**, 1, 1932, and Mandel, *Phys. Zeit. Soviet Union*, **2**, 286, 1932). If this is true, then positive and negative electrons must be created —presumably in pairs—during the collision between a cosmic ray and an atomic nucleus.

Why then have positive electrons eluded discovery for so long? The answer is that a positive electron can only enjoy a very short life as a free particle. Presumably, its life is ended by its ready combination with a negative electron to give two or more quanta of radiation. Such an end was foretold by Dirac, three years ago (*Proc. Roy. Soc.*, **126**, 360, 1930, and **133**, 60, 1931), in his theory of electrons, in which he pictured an electron falling into an unoccupied state of negative kinetic energy, and thus causing the simultaneous annihilation of a positive and a negative electron. The discovery of evidence of the existence of a positive electron will mean a renewed interest in Dirac's theory. Incidentally, he calculates that the mean free path in water of a positive electron of energy two hundred million electron-volts is somewhat over eight metres; the range of a negative electron of the same energy is about half a metre.

Finally, we may ask what is the nature of the primary cosmic radiation which produces these bursts, these showers, of electrons, protons and positrons? The electroscope measurements of the absorption of the radiation by water help us but very little, for we have little, or no, theoretical knowledge of the absorption processes to which such penetrating radiations are subject. The electroscope measurements of the geographical distribution of cosmic ray intensities, however, give us a strong hint, for the close correlation with magnetic latitude at once disposes of the hypothesis that the primary cosmic radiation consists entirely of photons, *i.e.* of ultra-penetrating γ-rays, and suggests that it must consist, in part at any rate, of charged particles.

The magnetic latitude effect discovered by Compton must be attributed to the charged constituents of the primary cosmic radiation alone. The effect arises because of the action of the earth's magnetic field upon charged particles coming towards the earth from all directions in space, an action which has been extensively discussed by Störmer (*Z.f. Astrophys*, **1**, 237, 1930, *Handbuch der Radiologie*, vol. VI) as the basis of his explanation of the origin of the aurora borealis. The trajectories of the particles are curved by the action of the earth's magnetic field, and certain conditions must be satisfied if any given particle is to reach the earth The above discussion was extended by Lemaitre and Vallarta (*Phys. Rev.*, **43**, 87, 1933), who showed that the experimental variation of intensity with magnetic latitude could be fully explained if the primary cosmic radiation consists partly of electrons or protons whose kinetic energy is of the order of 10^{10} electron-volts, travelling towards the earth in equal amounts from all directions in space.

This is convincingly set forth in Compton's paper (*Phys. Rev.*, **43**, 387, 1933), where it is shown that the observed cosmic ray intensities are not a function of geographical latitude, and that it is the geomagnetic latitude—not the local magnetic latitude determined from dip measurements in any locality—of which the cosmic ray intensities are a function. The latitude effect cannot be attributed to the bending which takes place in the earth's atmosphere, and the particles must originate some hundreds of kilometres from the earth's surface. Excellent agreement between the observed data and the Lemaitre and Vallarta curve for the intensity with magnetic latitude is obtained if it is assumed that a considerable portion of the ionisation at high latitudes is due to electrons with energies of about 7×10^9 electron-volts coming from remote space.

Other Contributions.—A big step forward in the production of high voltages for the investigation of problems of the structure

of the nucleus has recently been made by van de Graff, K. T. Compton and van Atta (*Phys. Rev.*, **43**, 149, 1933), who have made a new electrostatic generator of delightfully simple design. If we imagine a hollow metal sphere to be mounted on the top of an insulating tube, and that an endless band moves inside the tube, receiving electrical charges at the bottom and delivering them to the sphere at the top, we have a good picture of the basic idea of an electrode of the new generator.

In a model suitable for the generation of twenty-five micro-amperes at one and a half million volts in air, two electrodes, each consisting of a hollow sphere twenty-four inches in diameter, were used. Each was mounted on a seven-foot upright pyrex rod and charged with a silk ribbon band moving at a speed of 3,500 ft. per min. The operation of the generator occurred either by self-excitation or by charges being sprayed on to the two silk bands, as each passed between a metal surface and a set of metal points connected to a small 10,000 volt transformer kenotron set.

Plans are far advanced for the erection of a ten million volt generator of output about twenty kilowatts, in which the supports will be hollow cylinders of textolite, twenty-four feet high and six feet in diameter, and the spheres of aluminium alloy, fifteen feet in diameter. Inside each sphere will be a miniature laboratory and each pillar will be mounted on a truck of structural steel To make the vertical field of the generator more uniform each sphere will be connected to earth through a long spiral line of india ink drawn around the supporting cylinder. This artificial leak has been proved very advantageous in the case of the smaller generator.

Two new methods for the measurement of the ratio of the charge to the mass of an electron have recently been described. In the first, by F. G. Dunnington (*Phys. Rev.*, **43**, 404, 1933), a beam of electrons was given a continuous range of velocities by means of a high-frequency source of potential, as the beam passed between two metal slits. On emerging from the second slit the beam passed into a box provided with a series of baffles. A suitable magnetic field was applied, so that one component of the beam described a circular path inside the box and emerged through the first of another pair of metal slits. This component was decelerated between these slits and no electrons could pass on to a collector when the deceleration was complete. This condition was satisfied when the electrons took one complete period to pass from the first to the last slit.

It can be shown that in this case $e/m = \theta n/\mathrm{H}$, where θ is the angle in radians subtended by the path of the electrons, n is the frequency of the voltage supplied and H is the applied magnetic field.

It will be noted that it is not necessary to know the value of the applied voltage. H was comparatively small and it was necessary to allow for the earth's magnetic field, which was determined by rotating a coil, connected to a valve amplifier and valve voltmeter, inside a Helmholtz coil system; the current supplied to the latter was sufficient to produce neutralisation of the earth's field when no change in deflection of the voltmeter was recorded. The value of e/m thus obtained was $1{\cdot}7571 \pm 0{\cdot}0015 \times 10^7$ e.m.u. per gm.

In the second method G. C. Kretschmar (*Phys. Rev.*, **43**, 417, 1933) used the photo-electrons liberated by X-rays from thin metallic films, molybdenum K radiation of known frequency was employed and the several absorption levels of the metallic films were accurately known. The radii of the circles, in which the electrons ejected from these levels were forced to move under the influence of a known magnetic field, were measured by the usual method. The determination was based upon the assumption of an accurate value for h/e, but no accurate knowledge of the velocity of the photo-electrons was required. The value of e/m thus obtained was $1{\cdot}7570 \pm 0{\cdot}0026 \times 10^7$ e.m.u. per gm. The agreement between the above values is exceedingly good.

A highly accurate determination of the magnetic moment of the lithium atom is described by Meissner and Scheffers (*Phys. Zeit.*, **34**, 48 and 245, 1933). Their best results were obtained by the Gerlach and Stern deflection method, using a tungsten wire to receive the deflected atoms. The wire was electrically heated and kept at a high temperature. The alkali atoms which fell upon it were reflected as ions, and consequently a positive thermionic current flowed from the wire. This thermionic current was measured and the curve of thermionic current plotted against position of the wire allowed the separation of the two deflected beams of lithium atoms to be measured. From their determination the authors computed that the resultant magnetic moment of the core of the lithium atom could not be greater than five per cent. of a Bohr magneton, assuming that their magnetic field was sufficiently strong to produce independent orientation of the core and the valency electron. The value of the atomic moment was $0{\cdot}916 \times 10^{-20}$ gauss cm., which may therefore be regarded as the value of the Bohr magneton, with a possible error of about one-half per cent.

GENERAL AND ORGANIC CHEMISTRY.—By O. L. Brady, D.Sc., F.I.C., University College, London.

Infra-red photosensitisers.—The ordinary silver bromide gelatine emulsion of a photographic plate or film is most sensitive to

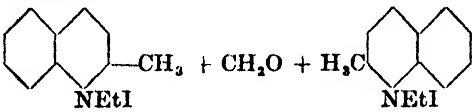
visible light of the shorter wave-lengths, that is blue and violet, and is practically unaffected by red light; for this reason a comparatively bright red light may be used in the dark-room when working with such plates. The introduction of the panchromatic plate was due to the discovery that if the emulsion was dyed with traces of certain organic dyes it became more sensitive to the longer wave-length light. The plate still remained much more sensitive to blue and violet than to red, but this could be corrected by placing before the lens of the camera suitable light filters which passed all the long wave-lengths but reduced the intensity of the light in the blue and the violet. By this means a much better tone rendering of multi-coloured objects was attained. Using an ordinary plate a bright red object would appear in the finished photograph much darker than a dark blue one, but with a panchromatic plate with the right light-filter the tones in the final print would be more in accord with the impression received by the eye, that is the bright red would be lighter than the dark blue

Recently a good deal of attention has been paid to the investigation of dyes which will render the photographic plate sensitive to light further and further into the red and infra-red portion of the spectrum.

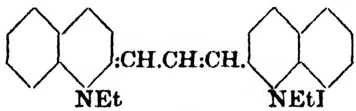
The indistinctness to the eye of a distant object in foggy or hazy weather is largely due to the scattering of the light from it by droplets of water in the air; now the longer the wave-length of the light the less is it scattered in this way, the fact that a red light is more easily seen in foggy weather has led to its almost universal adoption as a danger signal, so by the use of a red-sensitive plate in conjunction with a light-filter which lets through mainly light of longer wave-lengths much of the scattered light can be eliminated and clear photographs taken in foggy weather or telephotographs of far-distant objects usually obscured by haze. Plates of this description are of little use for artistic photography since the combination of abnormal colour-sensitiveness and filter produces great distortion of colour values—for example, green fields appear snow covered—but they are of great value scientifically, particularly in connection with surveying inaccessible regions by the Wilde Phototheodolite or for photo-map making from the air.

Recent photographs in the British press, such as one of the cliffs of Dover from Cape Gris Nez and an extraordinary one taken from the air in America showing a mountain-top 310 miles distant and demonstrating the curvature of the earth, have been made possible by the discovery of dyes which render the photographic plate sensitive even further into the red than those employed for making panchromatic plates.

The first practicable red-sensitising dye was pinacyanol, patented by Meister, Lucius and Brüning in 1905; this has an absorption maximum at $\lambda = 6{,}070$Å; in these sensitisers it is found that the position of the maximum of the band of extra-sensitivity corresponds approximately with that of the absorption band but shifted slightly towards the red. Pinacyanol, largely used for the manufacture of panchromatic plates, was obtained by the action of formaldehyde on quinaldine ethiodide (I) in the presence of alkali and was shown by Mills and Hamer (*J. Chem. Soc.*, 1920, **117**, 1550) to have the structure (II).

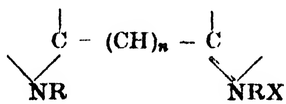


(I) (I)



(II)

The structure which appears to confer the peculiar red-sensitising effect on these dyes is a conjugated carbon chain joining two alkylated nitrogen atoms each of which is in a ring compound, that is the compounds have the general structure



or

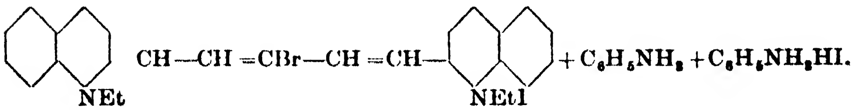
where R is an alkyl group and X an anion, n must obviously be an odd number.

By increasing the length of the unsaturated chain between the two nitrogen atoms the position of the absorption band in the spectrum of the dye shifts towards the red and the compounds sensitise the photographic emulsion to light of longer wave-length. Dyes of the pinacyanol type containing a chain of three carbon atoms between the heterocyclic nuclei have been designated carbocyanines and recently dicarbocyanines and tricarbocyanines have been prepared containing, respectively, five and seven carbon atoms in the chain.

Beattie, Heilbron and Irving (*J. Chem. Soc.*, 1932, 260), by the interaction of quinaldine ethiodide (I) and α-bromo-β-anilinoacralde-

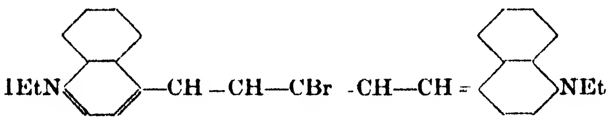
hyde anil (III) in pyridine in the presence of excess of piperidine, have prepared 11-bromo-1 : 1′-diethyl-2 : 2′-dicarbocyanine iodide (IV) (absorption maximum λ = 7,000Å).

(I) (III)



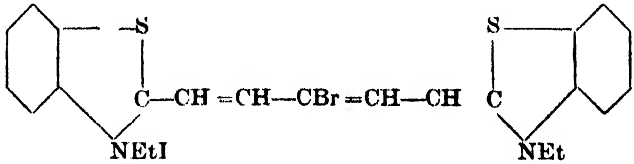
(IV)

By using lepidine ethiodide they obtained 11-bromo-1 : 1′-diethyl-4 4′-dicarbocyanine (V), the increase in length of the conjugated chain between the two nitrogen atoms produced by including the carbons of the ring shifted the absorption maximum to λ = 8,000Å

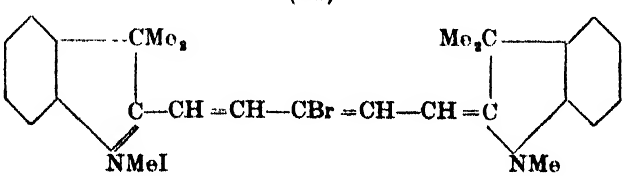


(V)

Among other compounds prepared are 11-bromo-4 . 4′-diphenyl-1 . 1′-diethyl-2 . 2′-dicarbocyanine iodide (absorption maximum λ = 7,000Å) from 4-phenylquinaldine ethiodide, 10-bromo-1 : 1′-diethyl-thiodicarbocyanine iodide (VI) (absorption maximum λ = 6,450Å) from 1-methylbenzthiazole ethiodide and 10-bromo-1 : 1′ : 3 : 3 : 3′ : 3′-hexamethylindodicarbocyanine iodide (VII) (absorption maximum λ = 6,450Å) from tetramethyl-indoleninium iodide.



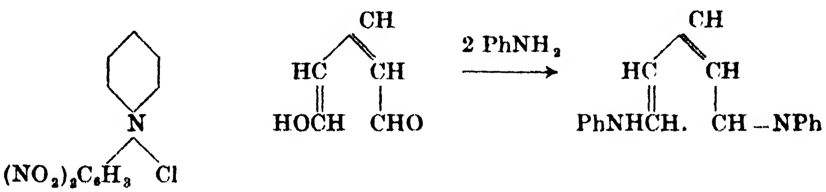
(VI)



(VII)

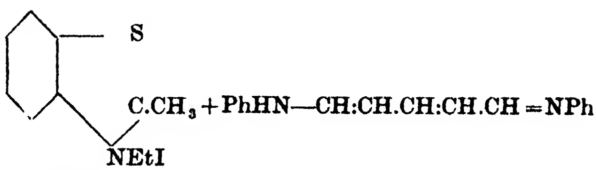
Three sets of workers have independently prepared tricarbocyanines containing two heterocyclic nuclei linked by an unsaturated seven carbon chain (Wahl, G. P. 499,967/1928; Piggott and Rodd, B.P. 355,693/1930; Hamer and Ilford Ltd, B.P. 351,555/1930, 354,826/1930).

Fisher and Hamer (*J. Chem. Soc.*, 1933, 189) have now given an account of their work. In their syntheses they make use of the extraordinary reaction discovered by Zincke (*Annalen*, 1904, **330**, 361) that when dinitrophenylpyridinium chloride (VIII) is treated with bases the pyridine ring is ruptured giving the enolic form of glutaconic aldehyde (IX) which combines with the base (aniline) to give an anilino-anil (X) analogous to the compound of Beattie, Heilbron and Irving.

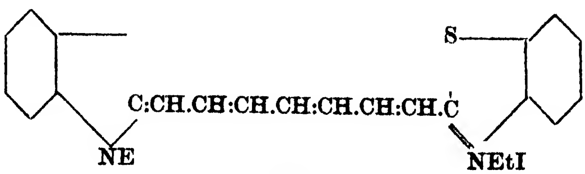


(VIII) (IX) (X)

This compound condenses with 1-methylbenzthiazole ethiodide (XI) to give 2 . 2′-diethylthiotricarbocyanine iodide (XII) (absorption maximum $\lambda = 7{,}650$Å).



(XI)

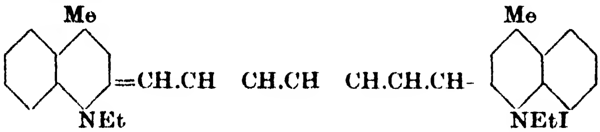


(XII)

Among other compounds prepared are 2: 2′-dimethylthiotricarbocyanine iodide (absorption maximum $\lambda = 7{,}600$Å) from 1-methylbenzthiazole ethiodide, 2 : 2′- diethyl-3 : 4 : 3′ : 4′ -dibenzthiotricarbocyanine iodide (absorption maximum $\lambda = 8{,}000$Å) from 2-

methyl-β-naphthathiazole ethiodide and a number of selenium analogues.

The tricarbocyanine analogue of pinacyanol, 1 : 1′-diethyl-2 : 2′-tricarbocyanine iodide from quinaldine ethiodide has an absorption maximum at $\lambda = 8{,}100$Å and its dimethylhomologue (XIII) from *p*-toluquinaldine ethiodide at $\lambda = 8{,}200$Å.



(XIII)

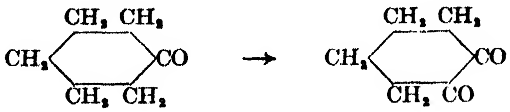
The human eye, generally, is unable to see light of a longer wavelength than about 7,000Å, consequently these dyes sensitise the emulsion into the infra-red considerably beyond the limit of vision, and just as photographs can be taken with the invisible ultra-violet to which ordinary plates are sensitive they can now be taken with the equally invisible infra-red. The advance from the absorption maximum at 6,070Å of pinacyanol to 8,200Å is remarkable, but the claim has been made that a very unstable dye, xenocyanine, sensitises up to 12,000Å (Block, *Photographic Journal*, 1932, 2).

A NEW OXIDISING AGENT.—The discovery of a new oxidising agent for organic compounds is something of an event, especially when the reagent is specific and puts at the disposal of organic chemists a means of preparing with some ease compounds of great interest which hitherto have been rather inaccessible in reasonable quantities.

For a considerable time it has been known that when commercial fuming sulphuric acid is used as an oxidising agent, for example, in the introduction of hydroxyl groups into anthraquinone and its derivatives, the trace of selenium dioxide present in such acid is the active oxidising agent, being reduced to selenium which is reoxidised by the sulphur trioxide $SeO_2 \longrightarrow Se + O_2$. $Se + 2SO_3 \longrightarrow SeO_2 + 2SO_2$. Riley, Morley and Friend (*J. Chem. Soc.*, 1932, 1875) have now shown that selenium dioxide or selenious acid has a specific action on aldehydes and ketones giving aldoketones, dialdehydes or 1 : 2-diketones. The aldehyde or ketone either alone or diluted with alcohol is boiled with selenium dioxide for from two to eighteen hours and the oxidation product isolated in various ways. The selenium can be reconverted to selenium dioxide by oxidising with nitric acid and subliming.

The following are some of the reactions described, the yield being calculated on the selenium dioxide employed:

$CH_3.CO.CH_3 \rightarrow CH_3.CO.CHO$ (12%).
$C_6H_5.CO.CH_3 \rightarrow C_6H_5.CO.CHO$ (50%)
$CH_3\,CH_2.CO.CH_3 \rightarrow CH_3.CH_2.CO.CHO$ (22%).
$C_6H_5.CO.CH_2.CH_3 \rightarrow C_6H_5.CO.CO.CH_3$ (50%).
$CH_3.CHO \rightarrow CHO.CHO$ (90% as bisulphite compound).
$CH_3.CH_2.CHO \rightarrow CH_3.CO.CHO$ (30%).
$CH_3.CH_2.CH_2.CHO \rightarrow CH_3.CH_2.CO.CHO$ (45%).


(35%).

Selenium dioxide also provides an easy means of distinguishing between fructose and glucose. When boiled with an acid solution of selenium dioxide fructose gives a red precipitate of selenium not produced by glucose, lactose or maltose, and only on prolonged boiling by sucrose.

Riley and Friend (*J. Chem. Soc.*, 1932, 2342) have found that selenium dioxide oxidises ethylene to glyoxal and propylene to methyl glyoxal but that higher olefins such as amylene, trimethylethylene, styrene, crotonaldehyde and cinnamaldehyde are not oxidised at their boiling-points, but at higher temperatures give complex oxidation products which are still being investigated.

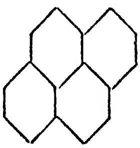
At higher temperatures selenium dioxide oxidises ethyl alcohol, Astin, Newman and Riley (*J. Chem. Soc.*, 1933, 391) showing that at 200° an appreciable amount of glyoxal is produced but that propyl and butyl alcohols give a variety of products and little methyl or ethyl glyoxal. They find that benzyl alcohol at its boiling-point gives an almost quantitative yield of benzyaldehyde free from benzoic acid, emphasising the rather remarkable fact that selenium dioxide does not attack the aldehyde group. Ethyl malonate gives about 10 per cent. of mesoxalic ester but ethyl succinate gave about 40 per cent. of a mixture of ethyl fumarate and ethyl hydrogen fumarate.

1 : 2-Benzpyrene, a Cancer producing Hydrocarbon in Coal-Tar.—The incidence of cancer of the skin among workers with coal-tar suggested the presence therein of a carcinogenic substance and Yamagiwa and Ichikawa (*Mitteil med. Facultät, kaiser. Univ. Tokyo*, 1915, **15**, 295) actually produced, for the first time, experimental cancer in mice by means of the products of the distillation of coal. Hieger (*Biochem. J.*, 1930, **24**, 505) found that there was a specific fluorescence spectrum (bands at 4,000, 4,180, 4,400Å)

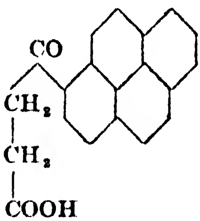
common to tars and mineral oils which produce cancer of the skin, and an important paper by Cook, Hewett and Hieger (*J. Chem. Soc.*, 1933, 395) deals now with the isolation of a cancer-producing hydrocarbon from coal-tar.

Working with two tons of a medium soft pitch, shown to be cancer-producing, and following the fractionation by means of the fluorescent spectrum, a compound has been isolated which has been found to be 1 : 2-benzpyrene. This substance, which was present in the original pitch to an extent of not less than 0·003 per cent., possesses the fluorescence spectrum Hieger associated with the carcinogenic substance and rapidly gives rise to malignant tumours of the skin of mice. For purposes of identification of the compound 1 : 2-benzpyrene has been synthesised

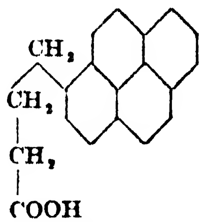
Pyrene (XIV) was condensed with succinic anhydride in nitrobenzene by means of aluminium chloride to give β-1-pyrenoylpropionic acid (XV) which was reduced to γ-1-pyrenylbutyric acid (XVI). Ring closure was brought about by anhydrous stannic chloride giving 4′-keto-1′ : 2′ : 3′ · 4′-tetrahydro-1 . 2-benzpyrene (XVII) which, on heating with selenium, gave the required 1 : 2-benzpyrene (XVIII).



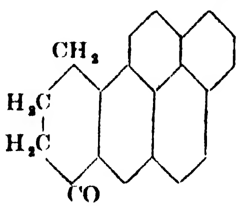
(XIV)



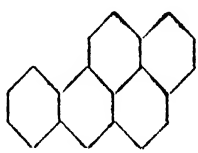
(XV)



(XVI)



(XVII)



(XVIII)

The synthetic material was identical with that isolated from pitch.

PHYSICAL CHEMISTRY. By O. H. Wansbrough-Jones, M.A., Ph.D., Laboratory of Colloid Science, Cambridge.

It is quite certain that much the most interesting single element is, at the moment, hydrogen ; the simplicity of its structure enables

calculations of its properties to be performed in detail that are impossible with other elements, while the different forms in which it exists allow of a variety of experiments to be performed in which the differences in physical properties of the single chemical individual play the deciding parts. It is particularly with reactions of the different kinds of hydrogen that this review will deal, and while some of the results that have been obtained are already well known, there have been several papers in the last few months which are of special interest.

Hydrogen is, of all the diatomic gases, the most readily accessible in the atomic state, and indeed atomic hydrogen is now of commercial importance in arc-welding processes. The reactions of atomic hydrogen with other substances are now fairly well worked out in a number of cases (cf. Bonhoeffer, *Ergebnisse Exakten Naturwiss.*, **6**, 201, 1927, for an early account), but by way of illustration the results obtained by Chadwell and Titani (*J.A.C.S.*, **55**, 1363, 1933) may be mentioned. Atomic hydrogen was obtained in the usual way by streaming hydrogen through a Wood discharge tube and allowing the active product, which may contain as much as 40 per cent. to 70 per cent. of atomic hydrogen, to mix and react with such substances as the alkyl halides. Relatively complicated products are formed in the reaction, which always takes place with the emission of a greenish-yellow chemi-luminescent light and a good deal of heat The analyses of the reaction products, both qualitatively and quantitatively, support the simple mechanism for the reaction $MeX + H = Me + HX$ which is exothermic to the extent of about 30 K cals. The subsequent life history of the methyl radicle colliding with the walls and with other bodies will then account for all the other substances formed in the reaction in a reasonable manner. The reaction with the ethyl halides leads to results that are rather too complicated to explain in detail. This reaction may be used as a type illustrating the use of hydrogen atoms as a reagent.

Another not uninteresting use of hydrogen atoms is in their own mode of recombination as an example of a simple chemical reaction, which might indeed be said to be the simplest possible one that exists. This has recently been re-examined by Amdur and Robinson (*J.A.C.S.*, **55**, 1395, 1933), the particular point at issue being the relative importance of the two possible modes of recombination, by three body collisions in the gas phase, and by collisions on the wall, and the respective parts played by atoms or molecules as the inactive partners in three body collisions. Smallwood (*J.A.C.S.*, **51**, 1985, 1929) had stated that atoms and molecules were equally efficient in

allowing the reaction to proceed, and had found a large wall effect. Senftleben and Riechemeier (*Am. Phys.*, **6**, 105, 1930) had found but a small wall reaction, and had attributed a greater efficiency to atoms than molecules when acting as third bodies. Steiner and Wicke (*Z. Phys. Chem. Bodenstein Festband*, 817, 1931) had made a thorough study of the reaction when the wall reaction was reduced by poisoning the surface with phosphoric acid, and had concluded that the three-body collision formula gave satisfactory results for the course of the reaction when a greater efficiency was ascribed to the hydrogen molecule as the third partner in the collision than to the hydrogen atom. It was found in this work that the constant given by the gas kinetic formula was some four times smaller than the reaction velocity constant determined experimentally. The theoretical implications of this discrepancy are of obvious importance and have received further study. In the most recent work of Amdur and Robinson, the main conclusion that the recombination is partly a wall and partly a three-body collision is confirmed as also is the relatively smaller efficiency of the atoms as third-body partners compared with molecules. Thus this very simple chemical reaction is reaching a state where its complete theoretical treatment can be checked by experimental observations.

The third main point of interest of hydrogen atoms lies in their participation in certain chain reactions as intermediate products. Though such a rôle has often been ascribed to them, as for example in the hydrogen chlorine chain reaction, and in certain autoxidation processes, it is only recently that direct experimental evidence of their existence, and indeed measurements of their concentration, has been forthcoming. Similar measurements have also been made to detect their presence as the primary products in certain photochemical processes. The experimental method is to use the transformation of para- to ortho-hydrogen as the index of their presence, and it will first be desirable to summarise the evidence on which the reliability of this test exists.

The experimental discovery of the two modifications by Bonhoeffer and Harteck (*Zeit. Phys. Chem.*, B, **4**, 113, 1929) and Eucken and Hiller (*ibid.*, 142) followed closely on the theoretical work of Dennison, who had shown that the different nuclear spins of the two forms would indeed lead to two modifications having different specific heats at low temperatures, existing in statistical equilibrium with each other in ratios of three parts of ortho- to one of para-hydrogen at temperatures above room temperature, approximately a 1 : 1 mixture at the temperature of liquid air, and practically pure para-hydrogen at the temperature of liquid hydrogen ; but that in such

modifications the transformation from the one form to the other was of the nature of a forbidden transition, and which could, therefore, only take place in special conditions. This gives a satisfactory explanation also of the hydrogen band spectrum. The means adopted by Bonhoeffer and Harteck to establish this experimentally were simple, the ordinary 3 : 1 mixture that is found at room temperature was adsorbed on charcoal, cooled in liquid air or liquid hydrogen, and the specific heat of the desorbed gas compared with that of normal hydrogen by making a comparison of their thermal conductivities. The theoretical predictions were completely established in this paper, the pure para-hydrogen obtained by the use of liquid hydrogen was shown to have a different melting-point and vapour pressure to the normal mixture, and the first point relating to the mechanism of the change was made when it was suggested that the presence of atoms of hydrogen was very possibly the deciding factor.

The mechanism of the reconversion of ortho- to para-hydrogen at high temperatures was much more completely examined by A. Farkas (*Zeit. Phys Chem.*, B, **10**, 419, 1930), who showed that the reaction was essentially homogeneous, taking place readily only when the thermal dissociation of hydrogen into atoms was considerable. Their concentration at any temperature may be calculated from the Nernst formula, and it was found that the rate at which the reaction proceeded at different temperatures and pressures agreed exactly with the kinetics that were to be expected from the formulation

$$H_{2\,\text{para}} + H = H + H_{2\,\text{ortho}}$$

in which the reaction took place with an energy of activation of 7,250 cals. That this was indeed the correct mechanism of this change was confirmed shortly afterwards by the work of Geib and Harteck (*Zeit. Phys. Chem., Bodenstein Festband*, 849, 1931) when the direct measurements of the velocity of the change of para-hydrogen in the presence of atomic hydrogen produced from a Wood discharge tube were made. The experimental arrangement for such a study was necessarily complex, but an examination of the results reveals that the rates measured were completely reproducible, and were in exact agreement with the energy of activation as determined by Farkas, while the fact that measurements at different temperatures had been made enabled the steric factor to be calculated, which was found to be about $\frac{1}{8}$.

It will now be clear that the converse method can be used to calculate the concentration of hydrogen atoms in any reaction in which their presence is suspected provided that the steric factor and

the energy of activation are taken to be those previously determined and that nothing else is present in the reacting system that will enable the equilibrium mixture to be attained in any other way. In fact, the presence of hydrogen atoms in the photochemical union of hydrogen and chlorine has been investigated by the same authors (*Zeit Phys. Chem*, B, **15**, 116, 1932) Mixtures of hydrogen and chlorine were illuminated and the thermal conductivity of the hydrogen determined after removing the chlorine by freezing it out. No change was found when normal hydrogen reacted with chlorine or when para-hydrogen was illuminated without the addition of chlorine, but when para-hydrogen was mixed with chlorine and illuminated the difference in the conductivity enabled the extent of the change to be calculated and from it the stationary concentration of the hydrogen atoms was found to correspond to a partial pressure of hydrogen atoms of from 0·8 to $4{\cdot}7 \cdot 10^{-5}$ mm, in the conditions of the experiment The existence of hydrogen atoms as a primary product of the photochemical decomposition of ammonia in the gas phase has been demonstrated in the same way.

As a chemical weapon, therefore, the rate of attainment of the statistical equilibrium between the two forms of the hydrogen molecule has proved of great value and interest in the study of some homogeneous reactions. Equally interesting are the results that have been obtained in studies of its heterogeneous conversion. That the equilibrium was practically immediately attained when the para-hydrogen was passed over platinised asbestos or palladium black, was shown by Bonhoeffer and Harteck in their original paper. The more recent work of Bonhoeffer and A Farkas (*Zeit. Phys. Chem.*, B, **12**, 231, 1931) has extended this to a detailed study of the manner of the decomposition on surfaces of gold, nickel, tungsten and other metals and in one or two cases, the accommodation coefficients of hydrogen on the metal have also been measured. It is clear that this provides a most useful method for the examination of adsorbed films on metal surfaces (cf. Roberts, *Proc. Roy. Soc.*, A, **135**, 192, 1932), and now Rowley and Bonhoeffer (*Zeit. Phys Chem.*, B, **21**, 84, 1933) have shown that certain definite conclusions may be drawn from a study of the relative accommodation coefficients of ortho- and para-hydrogen on a platinum surface. It is shown that this surface is always covered with an adsorbed layer of hydrogen, since the absolute value of the coefficient is too high to be given by a clean surface; secondly, the negative temperature coefficient of the accommodation coefficient indicates the transition from the low temperature Van der Waals adsorption to the activated or atomic adsorption; and thirdly, the lower accommodation

coefficient of para-hydrogen (15 per cent. smaller) indicates a less efficient interchange of rotational than of translational energy, the rotational accommodation coefficient having a strong negative temperature coefficient, which may indeed account for the whole variation with temperature. More work will certainly be done on surfaces with the aid of ortho- and para-hydrogen.

The rate of attainment of the equilibrium at high pressure had also been examined and in general it was found to be rather unreproducible, and to indicate that the reaction was primarily a surface one. Very recent work of L. Farkas and H. Sachsse (private communication) has thrown new light on the whole problem in general, as well as explaining the variations in these measurements. The new work consists in showing that the presence of very small amounts of paramagnetic substances causes the transformation of para- to ortho-hydrogen to take place, the substances that have been used in particular being oxygen and nitric oxide at pressures of the order of 20 mm. A most interesting point is that to the temperature of liquid air the reaction has no temperature coefficient, and is, therefore, really no chemical reaction in the normal sense, but has more the character of a physical change. The inverse reaction can also be shown to take place, for when hydrogen containing the normal three to one mixture and a little oxygen is cooled down to the temperature of liquid air, the equilibrium mixture of equal parts of the two modifications is quickly reached. It thus seems likely that the variations that were found in the experiments on the conversion at high pressures might have been due at least in part to the fact that the importance of small adventitious traces of oxygen had not been fully realised. Similar experiments have also been made in the liquid phase and it has been found that paramagnetic ions of some rare earths are particularly effective in promoting the change, when the para-hydrogen passes through the solution, while even dissolved oxygen is still effective. These last results help also to explain the results of Polanyi and Cremer in which the transformation in the solid and liquid phases of hydrogen has been shown to take place with no temperature coefficient, since this may be due to the magnetic field of the resultant nuclear spin of the ortho-hydrogen. It should, perhaps, be mentioned that Bonhoeffer and Harteck showed that the hydrogen ion in solution would not cause the conversion to take place, this failure being due, no doubt, to its great hydration. In the four years which have passed since the first samples of hydrogen enriched in the para-form were prepared its value as an aid to experimental studies has been amply demonstrated.

The existence of the hydrogen isotope of mass 2 became probable rather than speculative about eighteen months ago when Urey, Brickwedde and Murphy (*Phys. Rev.*, **39**, 164, 1932) found spectroscopically that this isotope was present to the extent of about 1 part in 4,500 in ordinary hydrogen, but that fractional distillation of liquid hydrogen near its triple point resulted in an enrichment of the heavier isotope to the extent of about 1 part in 800. In the light of more recent work (Bleakney, *Phys. Rev.*, **39**, 536, 1932) it seems that for normal samples of hydrogen this estimate is too high and that the lower concentration of about 1 part in 30,000 is nearer the mark. This figure would also render the failure of the mass-spectrograph to reveal this isotope in normal hydrogen understandable (cf. Kallmann and Lazareff, *Naturwiss*, **12**, 206, 1932, for other spectroscopical evidence). It might have been thought that since such very small amounts of the heavy isotope were present, it would not be of great or immediate interest to the chemist, but two recent pieces of work indicate that this discovery has presented the chemist with another valuable tool for the elucidation of a variety of problems.

In the first place, it is now possible to obtain far greater concentrations of the isotope than could reasonably have been hoped for. Washburn and Urey (*Proc. Nat. Acad. Sci.*, **18**, 496, 1932) suggested that fractional electrolysis of water might result in an accumulation of the heavier isotope in the remaining water. In the first place, the union of an electron to H^1 and to H^2 might well have a different potential, and the process having the lower potential will proceed almost to the total exclusion of the other; secondly, the actual formation of hydrogen gas involves the factors known comprehensively as polarisation, and there is no reason at all why the over potential that must be applied to cause the liberation of hydrogen gas should be the same for both species. Thus, fractional electrolysis should lead to the production of pure hydrogen of mass 1, and an equilibrium mixture of H^1 and H^2 in the remaining water in proportions that cannot be prophesied. Experiments to confirm this concentration of H^2 were commenced at the Bureau of Standards in Washington in December 1931, and the April number of the new *Journal of Chemical Physics* contains (Washburn, Smith and Frandsen, **1**, 288, 1933) the results obtained to the present. An accumulation of the heavier isotope was obtained great enough to produce water with a marked rise in the specific gravity, freezing-point, and boiling-point, and a decrease in the refractive index. No indication of the approach of an electrolysis equilibrium has yet been indicated, and it is hoped that it will be possible to obtain the various

isotopes of hydrogen and possibly oxygen in a pure state. It may be mentioned that in the first report of this work, it was stated that water taken from cells in which electrolysis for the commercial preparation of oxygen had been continued for some years showed a very marked increase in the amount of H^2 present and some indication of an increase in O^{18}. Similar experiments reported by G. N. Lewis (*J.A.C.S.*, **55**, 1297, 1933) have given a concentrate of specific gravity 1·035, meaning that the heavy isotope constitutes one-third of all the water present. The sample also showed a large decrease in the refractive index.

These results are of the greatest interest in themselves, but the fact that it should soon be possible to obtain H^2 almost in bulk leads to many fascinating speculations as to experiments that might be performed with its aid. Lewis believes that the properties of the new isotope will be totally different from those of H^1 and suggests that a new organic chemistry may be at hand, and indeed there seems no end to the number of interesting problems to which this discovery will lead. Some months ago the properties of the new isotope were used, if in a rather negative manner, by Polanyi and Cremer (*Zeit. Phys. Chem.*, B, **19**, 443, 1933) to examine a theory of contact catalysis that had been advanced by Born and Franck, in which it was suggested that the function of the catalyst was to hold the reacting molecules adsorbed in contact with each other for so long a time that the probability that they would get through the quantum-mechanical energy barrier and so react became large enough for reaction to be perceptible. The chance of such a process taking place—the tunnel effect—is a function amongst other things of the mass of the reactant, and Polanyi and Cremer calculate that the relative chances of the H^1 and H^2 isotopes reacting in their particular experiments are such that when the reaction with the lighter isotope proceeds at a conveniently measurable speed, the heavier will practically not react at all. The particular reaction in which the work was done was the reduction of styrol on a contact mass of palladium and barium sulphate. About three litres of hydrogen were shaken with styrol and the catalyst until the volume of hydrogen had been so decreased by the reaction that but 0·005 c.c. remained unchanged while the original amount of H^2 in the total gas must have been of the order of 0·1 c.c. If the tunnel mechanism had been the correct one and the heavier isotope been less reactive than the lighter, there must then have been a higher concentration of the heavier in the residual gas, but when the thermal conductivity of the residual gas was examined no change due to any alteration in the masses of the molecules was detected, though it would have been

readily detectable by the apparatus used. It would seem then that if the process determining the speed of the hydrogenation of styrol is really the speed at which the molecules react with each other on the surface, and not some more complicated diffusion process, this reaction at least is not an example of the tunnel effect. Probably the principal interest of this work lies not so much in the results obtained as in the fact that it is the first example of the use of the isotopes of hydrogen to tackle a chemical problem, a field in which it is certain that much interesting work will soon be being carried out.

There is but one further possible modification of hydrogen, the H_3 molecule, which Conrad (*Z. Physik.*, **75**, 504, 1932) believes that he had discovered in the stream of particles formed after canal rays have passed through an electrical field to eliminate the charged particles. The evidence is very indirect even though he believes it to be sufficient for him to estimate the mean life of the particle as about $3 \cdot 10^{-8}$ secs.; and against it, it should be stated that on quantum mechanical grounds the existence of this particle seems very unlikely, and Urey and his co-workers failed to detect it in the mass-spectrograph.

In the present state of chemical physics it is only possible to deal with the simplest molecules in detail, and of all the available molecules it is obvious that hydrogen will be the most tractable to mathematical methods The purpose of this review has been to show from some of the more important of the many experiments that have been made on it in the last few years, that sufficient detail has been accumulated to provide the mathematician with material to work upon. It will not be forgotten that some other special properties of hydrogen, and in particular the singular place of the hydrogen ion in experiments on the conductivity of solutions, have also been attracting attention of late.

BIOCHEMISTRY.

By W. O. Kermack, M.A., D.Sc., Laboratory of the Royal College of Physicians, Edinburgh.

Copper and Iron in Blood Formation.—Considerable attention has been given in recent years, especially by American workers, to the rôle of copper in the formation of blood pigment and red blood corpuscles. It was observed that rats brought up on a pure milk diet tended to develop an anæmic condition which might prove fatal and it was shown that the addition of copper to the milk was sufficient to effect a complete cure, provided that an adequate supply of iron was also available. An extensive controversy has raged over the question as to whether copper is the only substance

which is capable of bringing about regeneration of red blood corpuscles in this condition. It was shown by Lewis, Weichselbaum and McGhee (*Proc. Soc. Exp. Biol. and Med.*, 1930, **27**, 329) that copper, highly purified electrolytically, is active in minute doses, whereas very carefully purified iron was without effect even when administered in considerable quantities. Copper could not be replaced by either electrolytic iron or purified manganese. Other workers however, whilst agreeing that pure copper is highly active, claim that cure may also be effected by other substances; for example Drabkin and Miller (*J Biol. Chem*, 1931, **90**, 531; **93**, 39) assert that when iron is fed along with certain amino acids, especially glutamic acid and arginine, hæmoglobin formation takes place. This, however, is denied by Elveljem, Steenboch and Hart (*J. Biol. Chem.*, 1931, **93**, 197), who seem to consider that copper is the only active substance. The findings of Myers and Beard (*J. Biol. Chem.*, 1932, **94**, 89) would seem to indicate the need for caution in arriving at a final decision on the subject on the evidence at present available. These authors claim that pure iron alone is sufficient to bring about regeneration of hæmoglobin and erythrocytes, and, whilst agreeing that the process of regeneration is accelerated by copper, assert that a number of other elements, *e g.* nickel, germanium, manganese, arsenic, titanium, zinc, rubidium, chromium, vanadium, selenium, and mercury, have a similar effect. In fact, they find that although copper is the most active element when a particular dose of iron is administered, yet with other doses of iron it may not retain first place. In view of the fact that the quantities of copper involved are small (0·1 mg. per day), it seems prudent at the present time to accept as proved only the fact that copper is highly active in curing the condition and to leave open the possibility that under certain experimental conditions it may be replaced, in whole or in part, by some other substance. It may be that the thoroughness with which the animals have been deprived of copper preliminary to the observations is an important factor and that some of the apparent positive results may have been obtained with rats on a diet not entirely copper-free.

In the above work on the rôle of copper, it is important that there is no deficiency in iron as such, for iron, being an essential part of the hæmoglobin molecule, is of course necessary for normal blood formation. A recent paper by Elveljem and Sherman (*J. Biol. Chem.*, 1932, **98**, 309) shows very clearly the relationship between iron and copper in blood formation. To young rats, carefully brought up on a copper-free diet, were given liberal quantities of inorganic iron. They became markedly anæmic and the iron was

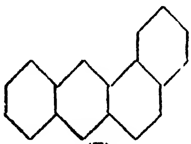
stored chiefly in the liver and spleen and apparently could not be utilised for the formation of hæmoglobin. If now the iron was withheld, and small quantities of copper added to the diet, the anæmia rapidly disappeared, blood corpuscles were formed, and the stores of iron in the liver decreased. It appears therefore that, in the absence of copper, the organism can absorb and store iron but is unable to convert it into hæmoglobin and that the presence of minute traces of copper is sufficient to allow the formation of normal blood corpuscles to take place freely. Results similar in nature, though possibly not quite so clear cut, had previously been obtained by Cunningham (*Biochem J.*, 1931, **25**, 1267), also working with young rats on diets containing minimal amounts of copper. This writer in her paper gives an interesting survey of the distribution of copper in the animal and vegetable kingdoms. She also discusses its possible functions, and in particular shows that it acts as a catalyst in the oxidation of dihydroxyphenylalanine to melanin by "dopa" oxidase. This might explain its presence in the ink sac of the octopus, for it does not appear to be a constituent of the pigment itself and is therefore probably concerned in its formation. It may be pointed out, that in view of the small quantities of copper required, it is not likely that copper anæmia would be frequently met with in human beings unless under very abnormal conditions.

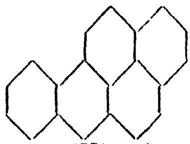
Carcinogenic Constituent of Coal Tar.—A recent announcement by Cook, Hewett and Hieger would appear to mark the beginning of a new stage in cancer research. For some time Cook and his co-workers have been investigating the substance in coal-tar which produces epithelioma in mice when applied to the skin surface over a considerable time. Some years ago the work of Hieger (*Biochem. J.*, 1930, **26**, 505) pointed to the association of the carcinogenic activity with a characteristic fluorescence spectrum and it was noted by him that a very similar fluorescence spectrum was given by certain derivatives of benzanthracene (I). Cook (*J.C.S.*, 1930–32) therefore undertook the synthesis of a considerable number of benzanthracene derivatives, so that their carcinogenic activity could be investigated. One or two were found to be active, but the activity did not appear to be very great. Cook and his co-workers (*Nature*, 1932, **130**, 926) have now succeeded in isolating a definite compound from coal-tar showing the characteristic fluorescence spectrum and exhibiting more marked activity than any other pure compound so far investigated. Further, the same compound has been prepared synthetically from inactive material and the synthetic compound has been found to have an activity equal to that of the

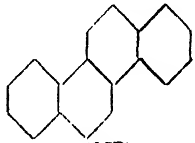
compound isolated from coal-tar. This carcinogenic substance is 1 : 2-benzpyrene and has the formula II.

It seems appropriate to point out here the remarkable similarity in structure which has recently come to light of four distinct groups of compounds all of which possess very great biological interest. These are (1) The Sterols, (2) Bile acids, (3) Œstrin, the compound isolated from the urine of pregnant females, capable of producing œstrus when administered to suitable animals, and (4) the carcinogenic compound mentioned above.

The fundamental basis in each case is the carbon skeleton III present in chrysene.


(I)


(II) *


(III)

Recent work of Rosenheim and King (*Chem. and Ind.*, 1932, 464) and Wieland and Dane (*Z. physiol. Chem.*, 1932, **206,** 243) indicates that either this or a closely related structure is the basis of the formula for cholesterol and the bile acids. According to the work of Butenandt and of Marrian the same statement holds for œstrin, whilst it will be seen that the chrysene skeleton is present in benzpyrene, for it is left when 2 carbon atoms, marked with asterisks in the above formula, are removed. It is therefore of very great interest that Cook has found (*Nature*, 1933, **131,** 56) that the carcinogenic substance (II) does actually possess definite œstrin-like activity. It is clear therefore that very interesting questions arise as to the biological relationship of these four types of compound, and further work on the subject will be awaited with the greatest interest.

Vitamins.—During recent years advances in our knowledge of the chemistry of the vitamins has been rapid and at times almost sensational. A very large number of original papers on the subject have appeared and it is possible here to give only some of the more important results.

Vitamin D.—When it was definitely proved that irradiation, with ultra-violet light, of ergosterol, a compound allied to cholesterol, resulted in the formation of vitamin D, the anti-rachitic vitamin, it was realised that the possibility of purifying this vitamin or of obtaining it in a crystalline form had been brought very definitely nearer. The hope was, in fact, soon realised, for in 1931 claims of obtaining vitamin D in a crystalline form were put

forward by Reerink and A. van Wyjk in Holland (*Biochem. J.*, 1931, **25**, 1001), by Windaus (*Proc Roy Soc.* B, 1931, **108**, 568) in Göttingen, and by Bourdillon and his collaborators working at the National Institute for Medical Research in London (*Proc. Roy. Soc.*, 1931, B, **108**, 340). These last workers gave the name calciferol to the crystalline compound, mp. 123–125°, which they were able to separate from irradiated cholesterol largely by the help of the well defined and readily crystallisable dinitrobenzoate mp 147–149°. Calciferol turned out to be identical both in chemical properties and physiological action with the compound isolated by Windaus and called by him vitamin D_2, and it is now generally agreed that this compound is, in fact, the vitamin itself and that its activity is not due to adventitious impurities The dose of the pure calciferol required to prevent rickets in rats is $0{\cdot}05 \times 10^{-6}$ g. per day.

When large quantities of crude vitamin D could be obtained by irradiation of ergosterol, it was soon realised that administration of excessively large doses to animals had a definite toxic effect. The question arose as to whether this toxic effect was due to the vitamin itself or to some associated impurity. It has been found by Bourdillon and others that this purified calciferol exerts, in large doses, essentially the same toxic action as the crude material, so that it would appear that excessive overdoses of vitamin D are definitely harmful to the animal organism.

Vitamin A.—Research on the other fat-soluble vitamin, A, has not resulted in a story quite so complete, but nevertheless very important developments have occurred. A new method of approach was opened up when von Euler definitely showed that animals, suffering as the result of lack of vitamin A, were much improved by the administration of carotene, the yellow pigment found in carrots, green leaves, and numerous other vegetables. It was soon apparent that the vitamin present in cod-liver oil was not itself carotene, as vitamin A concentrates, prepared from cod-liver oil, might have an activity quite out of proportion to the colour, on the assumption that the pigment carotene was itself the vitamin. Nevertheless, it was shown beyond doubt that the livers of rats, deficient in vitamin A, gradually became richer in that vitamin if carotene were administered to the animals. It therefore seemed clear that the animal body could convert the pro-vitamin, carotene, into the actual vitamin itself. Meanwhile intensive researches by Karrer, Morf and Schopp (*Helv. Chem. Acta.*, 1931, **14**, 1036) have resulted in the separation, from fish-liver oil, of a very highly concentrated vitamin A preparation for which absolute purity is not claimed but which is considered pure enough to justify the analytical results being

seriously considered. It is an oil although certain non-crystalline solid derivatives have been prepared. The empirical formula $C_{20}H_{30}O$ (or $C_{22}H_{32}O$) is given and a structural formula based partly on hydrogenation and oxidation experiments with the purified samples, and on the known facts of the chemistry of carotene and allied substances, has been suggested.

Essentially concordant results have been obtained by Heilbron and others (*Biochem. J.*, 1932, **26**, 1178). These authors carry out the final purification by distillation in a very high vacuum (0·00001 mm.) whereas Karrer and others employ the process of adsorption on alumina. Moreover, in following the course of purification, Heilbron and his collaborators make extensive use of the ultra-violet absorption band at 328 mμ, which would seem to be characteristic of the vitamin. They give general assent to the main features of Karrer's formula but they consider that even the purest preparations are definitely contaminated, though possibly not very markedly, by inactive constituents. The active doses of Karrer's and Heilbron's extracts are respectively 0·1 and $0·05 \times 10^{-6}$ g, but the variations may possibly be accounted for by variations in animal experiments.

Vitamin B.—Although the results so far obtained in the case of vitamin B are more ambiguous, some definite advances have to be recorded. Some years ago, it became apparent that vitamin B was not a single individual but that at least two distinct factors were involved. These were named vitamins B_1 and B_2, but it may be noticed that they are sometimes referred to as B and G respectively, especially by American workers. Vitamin B_1, sometimes called torulin, is the factor, the absence of which brings about the appearance of nervous symptoms, readily exhibited by pigeons (avian beri-beri). It is the factor with which Eijkmann was concerned in his original work, and is frequently called the anti-neuritic vitamin. Vitamin B_2 differs from B_1 in being alkali-stable, whilst the latter is alkali-labile, and it is the factor which prevents the development of pellagra, and, in rats, the onset of dermatitis. Later it was found that two further factors could be distinguished and these, after some preliminary confusion, were named B_3 and B_4. These factors are differentiated by their stability to heat and alkali and by their physiological effect on various animals.

Attempts to isolate vitamin B have usually been tried in relation to vitamin B_1. For example, from 50 kilos of yeast Windaus and his collaborators (*Z. physiol. Chem.*, 1932, **204**, 123) isolated a crystalline picrolonate in which sulphur was present as well as C,H,O, and N. To the base the formula $C_{12}H_{17}ON_3S$ was attributed. From rice polishings, Jansen and Donath had previously isolated a

crystalline base to which they attributed the formula $C_6H_{10}ON_2$, but the examination of this compound from rice polishings by Van Veen indicates that it contains sulphur and that it is possibly identical with the compound isolated by Windaus. In the case of Windaus' preparation, which appears to be the most active compound so far isolated, the anti-neuritic dose per pigeon is 1·4 to $3{\cdot}3 \times 10^{-6}$ g.

Vitamin C.—During the last two years, very striking advances have been made in our knowledge of vitamin C, the substance which prevents the development of scurvy in animals suceptible to this disease, the credit being due, in the first instance, to Szent-Gyorgyi. This worker was engaged, some years ago, in the study of various oxidation-reduction mechanisms in living cells. He was led to investigate more particularly a mechanism which was specially developed in the adrenal cortex of the ox but is also represented in other animal and vegetable tissues. He was able to isolate a crystalline compound on which this mechanism depended, and from its chemical analysis and properties, called it hexuronic acid. This name implied that it was derived from some non-specified hexose in the same way as glycuronic acid may be produced by the oxidation of glucose in the animal body under certain conditions. The compound exhibited very marked reducing properties, but the oxidised form was itself readily reduced back again to the original hexuronic acid. The interest in the compound became very much greater when it was pointed out by Tillmanns that a very close relationship existed between its distribution in animal tissue and the distribution of vitamin C as far as that was known, and Szent-Gyorgyi and Svirbely soon carried out experiments which led them to the view that vitamin C was in all probability none other than the crystalline hexuronic acid. These were published in March 1932 (*Nature*, 1932, **129**, 576) and almost simultaneously, Waugh and King (*J. Biol. Chem.*, 1932, **97**, 325) announced that they had isolated, from lemons, a crystalline compound with anti-scorbutic activity which was identical with hexuronic acid.

During the last year a very considerable amount of work has been carried out with a view to confirming or disproving these results. The chief difficulty in reaching an absolutely conclusive proof depends on the fact that, as indicated in the previous paragraphs, the active doses of vitamins may be of the order of 10^{-6} g. Now the active dose of hexuronic acid per day for guinea-pigs is 0·5 to 1·0 mg. ($500\text{–}1{,}000 \times 10^{-6}$ g.), so that the crystals might owe their activity to the presence of minute quantities of highly active material associated with them. In certain cases even repeated

recrystallisation will fail to remove slight traces of impurity from a compound and even fail to alter significantly the amount that is present. Various kinds of evidence have been brought forward, the cumulative effect of which appears to indicate that vitamin C may safely be assumed to be identical with hexuronic acid. For instance Svirbely and Szent-Gyorgyi (*Biochem J*, 1932, **26**, 865) have prepared a readily crystallisable acetone derivative. This compound after several recrystallisations was reconverted into hexuronic acid; the recovered compound was identical with the original hexuronic acid and possessed its anti-scorbutic activity in undiminished intensity. The chance of adventitious impurities continuing to remain associated with the compound after this treatment was clearly small. Harris and his co-workers (*Biochem J*, 1933, **27**, 303) after elaborating a method for the estimation of small quantities of hexuronic acid have carried out a survey of various plant and animal tissues and showed that there is essentially complete parallelism between their anti-scorbutic activity and their content of hexuronic acid. In particular, adrenal cortex of normal animals is found to possess specially high anti-scorbutic activity, in accordance with the fact mentioned above that Szent-Gyorgyi found it to be rich in hexuronic acid. Both Harris and Ray, and Svirbely and Szent-Gyorgyi have shown, that if guinea-pigs are kept on a diet deficient in vitamin C, the adrenal cortices of the animals become poor, not only in the vitamin, but also in hexuronic acid. In addition to this and other evidence of the same kind, it has to be added that so far the experimental facts on which the conclusions are based do not seem to have been called into question and no experimental evidence appears to have been put forward definitely inconsistent with the view that hexuronic acid is vitamin C. It should however be stated that Zilva, who has worked for many years on this subject, appears to consider that the question is still an open one and has brought forward some evidence which he considers is difficult to reconcile with the prevalent view.

The investigation of the chemical constitution of hexuronic acid was at first rendered difficult by the trouble of obtaining sufficiently large quantities of the pure compound. Fresh adrenal cortices could not be readily obtained in the requisite quantities, but Svirbely and Szent-Gyorgyi, working at the Hungarian University of Szeged, made the fortunate discovery that the juice of local varieties of the fresh, ripe, Hungarian red pepper, *paprika*, contained the acid in relatively large quantities (2 mg. per c.c.) and further that it happens to be relatively easy to separate it in a pure condition from this material. They describe a method whereby 15 g. of pure

recrystallised acid may be obtained from 10 kilos of juice and state that they have prepared 450 g. of vitamin C. This has enabled the constitution of the acid to be studied by Karrer in Zurich and by Haworth and Hirst in Birmingham The empirical formula is established to be $C_6H_8O_6$ in agreement with the original findings of Szent-Gyorgyi, but it is now clear that it is not really a hexuronic acid in the true sense In consequence Szent-Gyorgyi and Haworth have recently suggested (*Nature*, 1933, **131**, 24) that the name "ascorbic acid" should be given to the compound. Though the exact structural formula is not known it seems to be definitely established that the compound which is obtained when one atom of oxygen is added to it has the constitution COOH CO CO·CH(OH)·CH(OH)·CH_2OH (Hirst, *Chem. and Ind*, 1933, **52**, 222).

To obtain ascorbic acid from this compound, it is necessary to remove an atom of oxygen or to add on two atoms of hydrogen and remove a molecule of water Formulæ have been proposed by Karrer (*Biochem. Zeit.*, 1933, **258**, 4), Kraft and Micheel (*Nature*, 1933, **131**, 274), and Cox, Hirst and Reynolds (*Nature*, 1932, **130**, 888), but in view of the uncertainty which still exists we shall not quote here any of these formulæ. It is clear, however, that the complete solution of the constitution of ascorbic acid is only a question of time and it is interesting to realise that a problem, which takes us back to the days of Captain Cook and the early Polar explorers, is now apparently so near complete solution.

GEOLOGY. By G. W. Tyrrell, A.R.C.Sc., D.Sc., University, Glasgow.

Metamorphism and Metamorphic Rocks—According to V. Leinz (*Min. u. Petr. Mitt.*, **42**, 1931, 81–135) the amphibolite of the southern Odenwald varies in composition according to whether it is or is not in contact with later diorite or granite. It was produced by thermal metamorphism of diabase-tuffs by diorite, but at the contact of the two rocks there is a remarkable convergence in mineral and chemical composition. Where, however, the amphibolite comes into contact with granite it changes to hornblende-biotite-schist, and to pure biotite-schist when involved as inclusions in acid granite. These phenomena are explained in accordance with Bowen's views as due to a reaction process. Reaction with diorite of approximately the same chemical composition resulted in the precipitation of hornblende and plagioclase with which the diorite magma was saturated. Similarly reaction with granite produced those minerals, hornblende and biotite, with which the granite magma was already saturated. An editorial note asserts that this is an extreme view against which weighty objections may be urged.

In their paper "Über die metamorphen Gesteine bei Winterburg im Hunsrück," K. Chudoba and K. Obenauer (*N. J. f. Min., Beil.-Bd.*, **63**, Abt. A, 1931, 59–82) show that the country-rocks were phyllites of pre-Devonian age with lenses of sheared diabase. The phyllites have undergone transformation first to albitised sericite-phyllites, and further to crossite-phyllites, whilst the diabases have also been sericitised and albitised. The alteration is regarded as an autometamorphic effect consequent upon the intrusion of the diabase.

The intermontane (*zwischengebirgisch*) prasinite blocks of the Hainich-Borbersdorf district of Saxony have been exhaustively investigated by Dr. O. Weg (*Abh. Sächs. Geol. Landesanst*, H, **11**, 1931, 1–140). They appear to consist of overthrust and imbricated blocks pushed over the Saxon granulite foundation. The original rocks were probably diabases, porphyrites, and keratophyres, which have been transformed by epizonal dynamic processes into hornblende-epidote-schist (prasinite) and quartz-albite-schist. The prasinite facies passes into the greenschist facies with the development of actinolite in place of the non-alkalic, iron-rich hornblende (barroisite) of the prasinite group.

In his paper "Über die petrogenetische Ableitung des roten Erzgebirgsgneises," Professor K. H. Scheumann (*Min. u. Petr. Mitt.*, **42**, 1932, 413–54) conceives the red gneiss of the Erzgebirge as a true granite of ancient date with its magmatic associates and its contact aureole, which has been involved in the Variscian metamorphism. As a result of this work earlier views on the time succession of Variscian intrusions need to be revised.

In a paper entitled "Studien über die Metamorphose in Altkrystallin des Alpen-Ostrandes. I. Teil (Umgebung von Aspang-Kirchschlag)," H. Wiesenader (*Min. u. Petr. Mitt.*, **42**, 1931, 136–79) shows that the Aspang Granite is intruded into a series of crystalline schists, and that the rocks hitherto regarded as eclogites are really metasomatised amphibolites. The so-called diabases are dioritic differentiation products of the granite, and certain enstatite-rocks and anthophyllite-olivine-rocks are metasomatised materials attributable to reaction between amphibolites and dolomite-marbles.

A staurolite-andalusite-biotite-gneiss from Brissago, Tessin (Switzerland), has been shown by J. Suzuki (*Schweiz. Min. Petr. Mitt.*, vol. X, 1930, pp. 117–32) to have been derived from an iron-rich clayey sediment. Suzuki also describes a scapolite-amphibolite from Ascona in the same canton (*ibid.*, pp. 133–9). The Grialetsch-Vadret-Sursura Group, the petrography and geology of which have been described by F. Spaenhauer (*Schweiz. Min. Petr. Mitt.*, vol. XII, 1932, pp. 27–146), is a member of the Silvretta Crystalline Complex,

and belongs to the uppermost East Alpine nappes of the Swiss Alps. Ortho- and para-gneiss, mixed gneiss, amphibolite, crystalline dolomite and diabases take part in its structure. The detailed petrography of these rocks is exhaustively described.

The Danbury Granodiorite-gneiss of Connecticut, described by W. M. Agar (*Amer. Journ Sci*, vol XXV, 1933, pp 1–19), is an extremely variable formation consisting of sediments and basic intrusions which were affected by regional metamorphism accompanied by a diorite magma The depth of intrusion was so great that the igneous metamorphism amounted to partial fusion of the sediments, accounting for the coarse grain and porphyritic aspect of the complex A further tectonic disturbance granulated the rocks and was associated with *lit-par-lit* penetration by granite. The Kisseyenew Gneiss of Northern Manitoba and similar gneisses in Northern Saskatchewan are sedimentary in origin according to an investigation by E L. Bruce and A. F. Matheson (*Trans. Roy. Soc. Canada*, vol. XXIV, 1930, pp 119–32) All the rocks are thoroughly recrystallised and have a porphyritic habit through the development of secondary garnet or staurolite. In places the gneisses are interbedded with ancient volcanic rocks of both acid and basic types and are everywhere injected by granites These gneissic types are very widespread in Manitoba and Saskatchewan.

A "Petrologic and Structural Study of the Swakane Gneiss, Entiat Mountains, Washington," by A. C Waters (*Journ. Geol.*, vol XL, 1932, pp. 604–33), shows that, while originally made up of a diversified series partly of sedimentary and partly of igneous origin, metamorphism has been so complete that, save for differences in chemical composition, the complex has been welded into a homogeneous mass, which participates in a common foliation, and forms a single structural unit. Mylonites have been developed along later thrust planes.

In H. A. Stheeman's memoir on "The Geology of South-Western Uganda" (The Hague. M. Nijhoff, 1932, 144 pp.) interesting autometamorphic effects in granites, and allometamorphism of the adjacent schists, are recorded. Following the solidification of the granite tourmaline, and later, silica, was deposited, the silicification being accompanied by abundant deposition of white mica. Fluorine, boron and silica were added to the granite, whilst alkalis and alumina were extracted. Metamorphism in the surrounding schists followed a similar order of events.

Dr. K. Sugi's memoir, "On the Metamorphic Facies of the Misaki Series in the Vicinity of Nakagawa, Province Sagami" (*Jap. Journ. Geol. and Geog.*, vol. IX, 1931, pp. 87–142), describes a series of

andesitic-basaltic volcanic rocks, lavas and tuffs, of Miocene age, which are intruded by intermediate and acid plutonic rocks. The volcanic rocks have been altered with the production of greenschist, actinolite-greenschist, and amphibolite facies. The greenschists are considered to have arisen by intense dynamic metamorphism prior to the plutonic intrusions, whilst the amphibolites are believed to have been produced by the contact action of quartz-diorite intrusions, and are associated with skarn-like rocks.

MAJOR TECTONICS.—It is impossible adequately to summarise the points of such a comprehensive discussion as that which took place in Section E (Geography) of the British Association at the London meeting, on "Problems of the Earth's Crust" (*Geog. Journ.*, vol. LXXVIII, 1931, pp. 433–55; 536–44). Mr. A. R. Hinks made some pungent criticisms of current conceptions of continental drift, *polflucht*, mountain-building, and isostasy; Dr. Poole spoke on the thermal history of the earth; Professor A. Holmes discussed isostasy, the contraction hypothesis of mountain-building, and continental drift, stating that "if the continental masses (and ocean floors) are relatively passive in themselves and the source of activity is looked for in substratum currents then . . . the 'mathematical possibilities' of continental drift may turn out to be completely adequate." Dr. H. Jeffreys remarked that while Holmes's theory of substratum currents (see SCIENCE PROGRESS, Jan. 1932, p. 407) merited further examination its validity would be a remarkable accident. The position of the currents would be easily disturbed, and it would be unlikely for them to remain localised for whole geological periods.

In a paper entitled "Radioactivity and Theorising," Professor B. Willis (*Amer. Journ. Sci.*, **23**, 1932, 193–226) examines the hypotheses regarding the distribution of radioactive minerals in the earth and the heat effects attributable to them from the point of view of the method of multiple hypotheses. The theories are grouped under two headings: those that postulate some regular distribution of radioactive minerals in the globe, and those that assume irregularity of distribution. It emerges from the discussion that Professor Willis regards the first group of hypotheses (all by British investigators) as inconsistent with the facts, whereas the second group (by American authors) "appears to contain the seed of fruitful progress towards an understanding of the thermal, eruptive history of the earth." This is a most penetrating and valuable discussion.

P. Lake has written a very useful summary of Gutenberg's *Fliesstheorie* (*Geol. Mag.*, vol. LXX, 1933, pp. 116–21), which has been aptly described by Dr. H. Jeffreys as a theory of continental

spreading. Gutenberg considers that the continents, together with the Arctic, Atlantic, and Indian Oceans, constitute one great sheet of sial, which is less thick in the oceanic than in the continental regions. Only under the Pacific is the sial crust absent. The boundary between sial and sima is therefore the circum-Pacific girdle of fold-mountains and volcanoes The moon is believed to have carried away most of the sial leaving a single thick sheet placed asymmetrically about the South Pole. Under the influence of gravity the sial spread slowly outwards in all directions, but the *polflucht* force tended to drive it as a whole towards the Equator, mostly in the eastern hemisphere. Thus Gutenberg derives the existing distribution of continents and oceans.

In a Presidential Address to the Manchester Geological Association Dr. W. B. Wright puts forward some interesting speculations on the major tectonics of the earth, and especially on the history of the Tethys (*Journ. Manch. Geol. Assoc*, **1**, Pt. 3, 1932, 115–24). He is a strong advocate of continental drift and *polflucht* The late-Cretaceous and Tertiary mountain chains of the globe are shown to have the form of a theta (*e g* the circum-Pacific chain and the transverse belt of the Alpine-Himalayan system), and Dr. Wright also shows that the earlier Hercynian mountain-system followed the same mode of arrangement ; which is, however, much more difficult to discern in the Caledonian fold-mountain remnants. There follows the conception of a southward-moving equator, which is confirmed by the positions of equatorial oceans and hot desert belts of earlier periods. Dr. Wright finds the explanation of an equatorial Tethys in each period of transgression in the alternation of heating and cooling of the earth's subcrustal magma

H. Borchert's paper, " Über den Werdegang der subpazifischen Schicht und verwandte Probleme " (*Zeitschr. Deutsch. Geol. Ges.*, **84**, 1932, 761–78), is an attempt to analyse the magmatic and tectonic conditions existing in the sub-Pacific layer of the earth's crust. He believes that the subcrustal magma consisted of sial-sima (*i.e.* gabbro or basalt magma), and that the underside of the crust was its cooling surface whereon early crystallisation formed layers of dunite and pyroxenite, gravitative subsidence being inhibited by certain factors. By an ingenious combination of magmatic action, isostasy, and continental drift, he explains the mode of separation of continental blocks, and the formation of geosynclines and ocean basins. His conceptions are illustrated by informative serial diagrams, and he manages to explain the tectonic and magmatic differences between the Pacific and Atlantic ocean basins on his hypothesis.

Petrological study by Dr. A. W. Groves (*Geol. Mag.*, vol. LXIX, 1932, pp. 497–510) of the basement rocks of Uganda near the Lake Albert depression shows them to be all of the plutonic metamorphic type together with members of the charnockite series. Later shearing movements have caused micro-brecciation and granulitisation, and the rocks pass into mechanically foliated and thoroughly mylonised types. The intensity of this action appears to be related to distance from the nearest rift scarp. This and other evidence seems strongly to support the compressional theory of the formation of the Lake Albert Rift.

A. J. Bull has made interesting experiments on the surface forms produced on a contracting sphere (*Geol Mag.*, vol. LXIX, 1932, pp. 73–5), and shows that, while the lack of homogeneity in the earth's crust would make for irregularities, the pattern constituted by three anticlines or fractures meeting at a point should be the foundation of all tectonic structures on the hypothesis of a contracting earth. This is, however, not a characteristic mountain arrangement, and if it occurs at all, is rare. It is therefore concluded that the structures of the earth's crust have not been produced by a general contraction.

Dr. H. Jeffreys, however, criticises Mr. Bull's conclusions (*Geol. Mag.*, vol. LXIX, 1932, pp. 321–4) on the grounds that a considerable deformation can be produced in an elastic solid before its limit of strength is reached, and therefore before a permanent deformation has been induced. These are cases of elastic instability; and if they are to have any application to mountain formation evidence is needed that compression, under actual conditions in the earth's crust, will give instability before yielding. Fracture or yield would not give rise to general puckering but to long folded or fractured strips. Dr. Jeffreys thinks that elastic instability may be important in cases of readjustment to local stresses.

The late Professor J. B. Woodworth, who died in 1925, left an extensive series of notes on the subject of mountain-building, which have been carefully prepared for publication by A. C. Swinnerton (*Amer. Journ. Sci.*, vol. XXIII, 1932, pp. 155–71). The paper deals with I, The Orogenic Cycle; II, The Relations of Igneous Rocks to Mountain Building; and III, Appalachian Mountain Building. Professor Woodworth believed that to the orthodox succession of events in mountain building, *i.e.* geosynclinal accumulation and crustal compression, there should be added a phase of block-faulting. The block-faulted Newark Triassic deposits with their basaltic lavas and dolerite intrusions, following Appalachian orogeny, he regarded as one of the best examples of this succession. He does not, how-

ever, seem to have recognised the association of basic igneous rocks with the geosynclinal phase of orogeny.

A. Sieberg, in his paper "Zur Mechanik tektonischer Vorgänge" (*Zeitschr. Deutsch. Geol. Ges.*, **84**, 1932, 673–6), discusses the mechanics of tectonic processes from the point of view of a seismologist.

Thrusting is frequently thought of exclusively as the movement of older rocks over younger, but M. Billings (*Amer. Journ. Sci.*, vol. XXV, 1933, pp. 140–65) reminds us that younger rocks may be thrust over older in various ways, and shows that many thrust faults in which younger rocks rest on older have been confused with gravity faults or unconformities. In particular he suggests that some of the so-called normal faults in the Appalachians, Ouachitas, and other fold-mountain belts, may be thrusts of the above type.

T. S. Lovering has discussed the field criteria for distinguishing overthrusting from underthrusting (*Journ. Geol.*, vol. XL, 1932, pp. 651–63). "If a thrust fault breaks from an overturned fold in a zone of tear faulting, the movement of the walls of the tear faults shows the direction of movement of the adjacent thrust block and thus indicates whether underthrusting or overthrusting has taken place Similarly, a marked swing of formations towards or away from the axis of the overturned fold as a thrust fault is approached suggests underthrusting or overthrusting, respectively."

In the model scientific memoir on "Submarine Faulting in Kimmeridgian Times: East Sutherland," by Professor E. B. Bailey and Dr. J. Weir (*Trans. Roy. Soc Edin.*, vol. LVII, Pt. II, 1932, pp. 429–67), it is shown that during Kimmeridgian times a submarine fault-scarp was maintained by intermittent movement of the sea-floor of the Helmsdale district, while dry land existed to the north-west. Unconsolidated Mesozoic rocks on the upthrow side of the fault disintegrated without yielding boulders, but Old Red Sandstone exposed in the fault-scarp furnished repeated landslips carrying boulders that exceptionally amounted to 100 feet in length. The fault-scarp separated a shallow-water assemblage of organisms from a deep-water facies. Earthquakes must have been frequent for the landslip debris is almost always spread out into graded boulder-beds in a manner indicating the co-operation of tunamis ("tidal waves"). Earthquakes are also registered by fissuring of the Kimmeridgian and the production of chasm-breccia along the fault.

Phenomena bearing a strong family resemblance to those dealt with by Bailey and Weir are described by C. L. Baker (*Journ. Geol.*, vol. XL, 1932, pp. 577–603) from the Middle Pennsylvanian of Texas. Fragments ranging in size from pebbles to a maximum of

135 feet in the greater dimension are embedded in an arkosic or greywacke matrix, and have been derived from a rock succession about 10,000 feet in thickness. Exotic boulders occur along with those indigenous to the region. Important folding had occurred before the boulder-beds were formed; and the rocks have been greatly deformed by subsequent folding and thrusting. The boulder-beds are believed to represent true sediments and not mylonites. They may have been derived as a consequence of possible diastrophic events, or may have been ice-transported The author does not appear to have considered the hypothesis of contemporaneous submarine faulting.

In his valuable memoir, "Zur Geschichte der Adria: eine tektonische Studie," F. Baron Nopcsa (*Zeitschr. d. Deutsch. Geol. Ges.*, **84**, 1932, 280–316) figures a fine section of submarine land-sliding in the hornstone-bearing limestone of the Hauterivian of Monte Gargano. He ascribes the characteristic contortions to gliding during the consolidation of the strata.

G. Keller discusses the relation between sedimentation and folding in the Upper Carboniferous of the Ruhr (*Zeitschr. d. Deutsch. Geol. Ges.*, **84**, 1932, 577–606), and E Stach (*ibid*, pp. 607–18) maintains the essential contemporaneity of sedimentation and folding in the Ruhr and other regions.

E. Kraus (*Geol. Rundsch.*, vol. XXII, 1931, pp. 65–78) describes the Alps as a *Doppelorogen*, *i.e.* as composed of two orogenetic zones, derived from different geosynclines, which approach closely together, and have reciprocally influenced each other's course of development.

In his paper on "Ostalpines und Böhmisches Grundgebirge" (*Mitt. Geol. Ges. Wien.*, vol. XXIV, 1931, pp. 28–37), Professor F. E. Suess develops the view that the crystallines of the central zone of the Alps certainly do not represent a continuation of the Bohemian Grundgebirge. Neither in the Pennines, nor in the Austridian basements are found recognisable members of either of the two very dissimilar regions, the Moldanubian and the Moravian, of which the southern part of the Bohemian Mass consists.

The thesis of Professor R. Staub's memoir, "Die Bedeutung der Apuanischen Alpen im Gebirgsbau der Toskana nebst einigen Gedanken zur Tektonik des Apennins" (*Vierteljahr. d. Nat. Ges. Zürich*, Ser. B, vol. LXXVII, 1932, pp. 184–248), is that the Apennine Range is not a tectonic unity, for in Tuscany the Alpine fold lines divide into two main branches, the Tuskides turning due south into Sardinia, and the Italides which continue south-east down the Italian peninsula accompanied by representatives of the Adriatic-

Atlas folds. The Tyrrhenian intermont (*Zwischengebirge*) is enclosed between the two arms.

In his paper on " Die Stellung Siziliens in mediterranen Gebirgssystem " (*ibid.*, pp. 159–82), Professor Staub recognises in the southern ranges of Sicily representatives of the North African Atlas system and therewith the Moroccide element in Europe. Sicily is the theatre of a European virgation of Dinarides and Maroccides. The Apennines of the Basilicate Abruzzi and Umbria are not the continuations of the Atlas system, but these participate with the African element in forming the tectonic framework of Sicily.

ZOOLOGY. By Professor F W. Rogers Brambell, B.A., Ph.D., D.Sc., University College of North Wales, Bangor.

The second David Ferrier Lecture of the Royal Society was delivered by Ariëns Kappers (*Phil. Trans R.S*, B, **221**, 1932) on the subject of the correlations existing between the form of the skull and the brain. The subject, which is dealt with in detail, is introduced by a consideration of the correlations in the lower vertebrates, in birds and in mammals other than man, but the greater part of the lecture is devoted to man. It is pointed out that the study of the fissuration of the brain, from the point of view of its applications to palæontology and anthropology, is especially illuminating in view of the work of physiologists and histologists which has defined the functional significance of many regions of the surface of the brain. It is shown, however, that mechanical as well as functional correlations influence the surface anatomy of the human cerebral hemispheres.

The endocranial cast of the adolescent skull of *Sinanthropus* is described in a paper by Davidson Black (*Proc R.S*, B, **112**, 1933). It is shown that the cranial capacity of this adolescent *Sinanthropus* approximated to 960 c.c.; a volume which is within the lower limits of the range of variability of the cranial capacity of several modern races of man. It is suggested that this is not surprising since *Sinanthropus* was able to use fire and to make crude stone implements. The grooves marking the relations of the chief vascular channels show that the latter were arranged on a plan essentially similar to that most commonly found in modern man. The cerebellar region of the cast shows that the right side of the cerebellum was better developed than the left. The left hemisphere of the cerebrum appears also to have exhibited a less marked but definite superiority over the right. Since the right side of the cerebellum and the left side of the cerebrum are both concerned with the right side of the body, it would appear from the endocranial cast that the organs of the right side of the body were dominant over those of the

left. This conclusion is in agreement with that of Teilhard de Chardin and Pei (*Bull. Geol. Soc. China*, **11**, 1932), who state that the stone artefacts associated with the fossil remains of *Sinanthropus* appear to have been used with the right hand. That part of the *inferior frontal region of the cast, which in modern man is known to contain the motor speech centre, is remarkably well developed. It is* considered that this probably indicates that *Sinanthropus* possessed the mechanism of articulate speech. Broadly the endocranial cast presents an interesting mixture of archaic, generalised and progressive characters.

The anatomy of the Bushman Brain is dealt with in a paper by Slome (*Jour. Anat.*, **67**, 1932) who finds certain primitive features in the structure of the brain and that the total weights of the brains and the weights of the hemispheres are very small, being lower than that of any other living race recorded.

The comparative anatomy of the brain in the Insectivora is dealt with in a very interesting paper by Le Gros Clark (*Proc. Z.S. Lond.*, 1932). The cerebral anatomy of this group of mammals, particularly important since they are the most primitive living Eutherians, has not been dealt with adequately previously. The brains of sixteen genera, representing the Tenrecoidea, Erinaceoidea, Soricoidea, Chrysochloridea, Macroscelidoidea and Tupaioidea, are dealt with and the results are discussed from the evolutionary point of view, especially with the reference to the affinities of the Tupaiidea or Tree-shrews with the Primates. It is shown that the general structure of the brains of the tree-shrews supports the idea that they represent stages in cerebral development leading from a primitive Erinacoid type to one characteristic of simple Primates. The arguments, drawn from the anatomy of parts of the body other than the brain, for and against the view that the Tupaiids represent a group of progressive insectivores which may have given rise to the primitive lemuroids, are discussed briefly. It is maintained that the anatomical evidence as a whole strongly supports the view that the tree-shrews are allied to primitive Primates, especially in view of the recent discovery of *Anagale gobiensis*, a fossil Tupaioid from the Oligocene of Mongolia which has been described by Simpson (*Amer. Mus. Novitates*, No. 505, 1931), and is undoubtedly very closely related to the Tupaiidæ, although in some respects more primitive than the living representatives of this group. It approaches primitive Primates, on the other hand, more closely than do recent Tupaiids in a number of important characters and thus provides an even closer link with them. Thus the Tupaioidea provide a link between these two orders and it is a matter of discussion in which they should

properly be included. But even if they should be classified as primitive Primates the study of the structure of the brain in comparison with that of primitive lemuroids shows that they are much more primitive and that a considerable structural gap separates them.

Our knowledge of the comparative anatomy of the *autonomic nervous system in lower vertebrates has been very incomplete and* it has been impossible in consequence to form anything like a clear picture of its phylogenetic history. Recently our knowledge has been increasing and has received a material addition in the work of Young (*Q J.M.S* , **75,** 1933) on the anatomy and histology of the Autonomic Nervous System of Selachians In mammals the visceral motor nerves, forming the autonomic system, are divided into two sets, the sympathetic system and parasympathetic. The sympathetic system consists of the thoracico-lumbar outflow and the parasympathetic of the cranio-sacral outflow. In mammals the sympathetic and parasympathetic have opposite or antagonised effects on the visceral muscles, the one causing slackening and the other contraction of a given muscle. The pre-ganglionic fibres of the sympathetic system run in the ventral roots only of the spinal nerves. On the other hand the fibres of the parasympathetic run partly in dorsal roots and partly in ventral roots, the former being the case in the VIIth, IXth and Xth cranial nerves, while the latter is the case in the IIIrd cranial nerve and the sacral outflow. The phylogenetic origin of this arrangement is thus of great interest. In *Amphioxus* there is no true autonomic system but the fibres supplying the smooth muscles of the body run through the dorsal root nerves. It is probable in view of this that the dorsal roots constitute the primitive path of the visceral motor fibres. If this assumption is correct the real problem is how do they come to run out through the ventral roots in mammals except in the VIIth, IXth and Xth cranial nerves. Goodrich has suggested that the preganglionic fibres retain the primitive path in the dorsal roots in those segments in which the dorsal and ventral roots do not join but that they come to run through the ventral roots in those segments where the dorsal and ventral roots do join.

In Selachians visceral motor fibres are present in almost every segment in front of the anus, and they run through the dorsal roots in the VIIth, IXth and Xth cranial nerves and through the ventral roots in the IIIrd cranial and spinal nerves. The sacral parasympathetic outflow of mammals and other tetrapods is absent in Selachians. Although the sympathetic ganglia of adjoining segments are sometimes connected there are no well developed pre- and post-ganglionic pathways giving rise to a true sympathetic

chain on each side and the arrangement is thus more nearly segmental than in higher forms. Further the only region of the gut where the fibres from the vagus and sympathetic overlap is in the pyloric region of the stomach and, even here, there is little evidence of an antagonistic action. There is thus no clearly marked functional differentiation between the sympathetic and para-sympathetic systems of Selachians. It is suggested that these systems in tetrapods represent specialisations within a primitively single segmental set of visceral motor fibres. This specialisation being brought about by the overlap of the two systems caused by the backward spreading of the vagus supply to the gut wall rendering antagonisation possible in this region. Primitively the visceral motor fibres ran through the dorsal roots but they came to pass into the ventral roots in those segments in which the roots join.

The development of the ectodermal nerve-net in the buds of Hydra has been studied by McConnell (*Q.J.M S.*, **75**, 1932) It is shown that the nerve-net of the bud is not inherited from the parent Hydra nor is it developed from the very few ganglion or sensory cells of the parent reticulum which happen to be within the area where the bud is formed. The nerve-net of the bud is developed from interstitial cells which are multiplied at the place where the bud will originate The cells of the nerve-net of the bud remain undifferentiated until just before the rudiments of the tentacles appear. The net is formed by the pseudopod-like extension between the epithelio-muscular cells and final growing together of the processes of the ganglion and sensory cells. Differentiation of the net begins at the mouth-end and proceeds towards the foot. The long connecting sensory processes of the cells develop first and the short, free-ending motor processes later, but it is clear that both are formed as the cells differentiate and do not arise from pre-existing protoplasmic strands joining the cells.

The structure and development of the nasal glands of birds is dealt with in a paper by Marples (*Proc. Z.S. Lond.*, 1932). These glands lie above the orbits in grooves in the bone, which are conspicuous features of the skulls of many birds. There are two glands and two ducts on each side, one duct opening on the median and the other on the lateral wall of the nasal vestibule in most species. The Galliformes have only a single duct on each side with an opening on the median wall of the vestibule. The glands consist of tubules with radiating diverticulæ and their secretion consists of a slimy mass of degenerating cells. The glands are much better developed in marine than in terrestrial species and it is suggested in consequence that the function of their secretion may be to protect the nasal

mucosa from the effects of sea water. During development the glands and ducts arise as epithelial backgrowths from the lining of the nasal cavity. They are shown to be homologous with the nasal glands of other vertebrates and are not connected in any way with Jacobson's Organ.

A description of the Chromosomes of the Domestic Chicken is given by White (*Jour. Genetics*, **26**, 1932) who studied them both in somatic cells and during spermatogenesis Special methods of fixation were employed which appear to have reduced the "clumping" of chromosomes to a minimum The diploid number of chromosomes was found to be 66 ± 2 and the haploid number 33 ± 1. The chromosomes vary greatly in size, many being very small. It is probable that the smaller number of chromosomes reported in this species by previous workers was due to error introduced by clumping of the smaller chromosomes during fixation. The largest pair of chromosomes in the male is represented by a single element in the female These are regarded in consequence as the sex-chromosomes No sign of a W-chromosome was observed.

An extensive monograph on the anatomy of the Tortoise by the late Dr. J. Stuart Thomson has been published posthumously by the Royal Dublin Society (*Sci. Proc. R D S* , **20**, 1932). The work provides a very complete description of the osteology and general anatomy of the soft parts of the Iberian and Greek Tortoises, *Testudo ibera* and *T græca*. It is illustrated with many line figures. Such a monograph should prove of great use in teaching the anatomy of this important type and the practical suggestions for killing and dissection will be found to be valuable.

The nephridia of the adult *Asymmetron* are described and figured for the first time in a paper by Goodrich (*Q.J.M.S.*, **75**, 1933) and are compared with those of *Branchiostoma* (= Amphioxus). In view of the peculiar interest attached to the excretory organs of *Amphioxus*, on account of their resemblance to the protonephridia of many invertebrates and their fundamental difference from the nephric tubules of vertebrates, such a description of these organs in the allied genus *Asymmetron* is of importance. It is shown that the paired nephridia of *Asymmetron*, though smaller and simpler in structure, are fundamentally similar to those of *Branchiostoma*. Each consists of a triangular flattened sac, into which numerous solenocytes open, with an external pore opening into the atrium. The first nephridium on each side lies near the antero-dorsal margin of the first gill slit, as in *Branchiostoma*. Each nephridium after the first lies near the top of a secondary bar and projects into the suprapharyngeal cœlom. There is an unpaired nephridium of

Hatschek in the head region on the left side in *Asymmetron*, which resembles that in *Branchiostoma* also.

The structure and functions of the so-called anal gills of the larva of the yellow-fever mosquito (*Ædes* (*Stegomyia*) *argenteus*) are investigated in a series of papers by Wigglesworth (*Jour. Exp. Biol.*, **10**, 1933). The structure of the gills and the effect of salts on them are dealt with in the first paper. The so-called gills are finger-like processes with a delicate chitinous investment, and a lining of flattened cells. The cells are bounded internally by a continuous elastic membrane and elastic fibrils in the cells bind this to the outer chitinous cuticle. The gill is filled with hæmolymph. The gills, when cut off, swell in hypotonic salt solutions and contract in hypertonic solutions. The gills on intact larvæ placed in similar solutions, which come in contact with their outer surfaces only since they are filled with hæmolymph, behave very differently. Hypotonic solutions have no visible effect. No doubt under these conditions, or when the larva is in fresh water in its normal environment, the cells will tend to swell by absorbing water through the cuticle, owing to their internal osmotic pressure. This swelling will be resisted by the elasticity of the cells and by the osmotic pressure of the hæmolymph. It is thus almost certain that water will be absorbed through the anal gills in normal circumstances and will subsequently be excreted by the Malpighian tubules. The effects of hypertonic solutions of salts and of dilute alkalis and acids are also described and discussed. It is shown experimentally in the second paper, by ligation of the larva at various levels, that water is in fact absorbed by the anal gills when the larva is in fresh water and that they are the only part of the body freely permeable to water. Larvæ can mature without gills but grow more slowly. Normally the larva swallows very little fluid and that seen in the gut is probably excreted by the posterior part of the mid-gut. It is shown also that oxygen is absorbed by submerged larvæ all over the body surface but most actively at the base of the gills. Carbon dioxide is given off equally all over the body surface. It is concluded in consequence that the anal gills are primarily organs of water absorption and are only incidentally concerned with respiration.

The third paper is concerned with the adaptability of these mosquito larvæ to life in salt water. Normally the larvæ reared in fresh water are killed by 1·1 per cent. NaCl or by sea-water isotonic with 1·3 per cent. NaCl. The larvæ can be made resistant, by gradually increasing the concentration, to these solutions and even to sea-water equivalent to 1·75 per cent. NaCl (50 per cent. sea-

water). The larva is thus homoiosmotic in both fresh water and in hypertonic salt-water. This physiological adaptation appears to be brought about by (*a*) a strengthening of the elastic fibrils in the cells of the gills rendering them more resistant to swelling; (*b*) changes in the cells of the mid-gut epithelium, so that they do not swell up and are able to absorb salt-water; and possibly (*c*) by the Malpighian tubes excreting a more concentrated urine accompanied by an increased reabsorptive activity of the rectum.

ARCHÆOLOGY. By E. N. Fallaize.

The East.—Early reports of field work to hand at the time of writing point to a profitable season's work in the East. A new undertaking is the excavation of Tell Duweir by the Wellcome Historical Museum under the direction of Mr. J. L. Starkey. The Tell is situated about twenty-five miles south-west of Jerusalem, standing about 900 feet above sea-level and dominating the Philistine country. One of the principal points of interest in this excavation is the tentative identification with the city of Lachish, one of the cities of Palestine captured by Joshua after considerable difficulty. It was one of the strategic points of Southern Palestine, and should the identification be borne out by this excavation, much of interest for the early history of the Hebrews should accrue. While nothing which would directly disprove it has come to light in the course of the first season's work, several features tend to confirm it. The mound is some forty acres in extent at the base and about eighteen acres at the summit. Excavation has revealed that the stone walls of the city had at one time been breached, and subsequently had collapsed under the effects of a conflagration. According to the story of Lachish it was captured by Sennacherib in 701 B.C.—a siege depicted in bas-reliefs from Nineveh now in the British Museum —and destroyed by Nebuchadnezzar in 586 B.C. Beneath the stone walls were found walls of red brick which are thought to be the walls of Joshua's city, but their further examination had to be deferred until next season. Part of a Royal palace on the top of the mound has been uncovered. A large number of pottery fragments ranging in date from early Iron Age to the seventh century B.C. have been found, and a number of tombs at the base of the hill of all ages have been opened and have yielded a large number of skulls.

An expedition in Northern Mesopotamia which is yielding remarkable material of early date is that of the University of Pennsylvania Museum and the American School of Oriental Research

at Tepe Gawra, where a city dated at 3700 B.C. has been found. The expedition has now penetrated the levels below this city and has discovered the remains of a temple of comparable, but rather cruder, structure than that in the levels above. In the centre of the temple there is still the pedestal upon which the effigy of the deity once stood. Several tombs have been examined. These are considered to antedate the Royal Tombs of Ur. Among the contents of the tombs are plaques and combs of ivory and beads of gold, lapis-lazuli and carnelian.

The excavation of Tepe Gawra, however, gains in significance when considered in relation to the excavation of Tell Billa, a site eight miles to the east. The excavation of this mound was undertaken jointly by the University Museum, Philadelphia, and the American School of Oriental Research, the work beginning in October, 1930. A preliminary account of the pottery has recently been published in the *Museum Journal* (Philadelphia), Vol. XXIII, Part 3, by Dr. E. A. Speiser. The author there deals with the results of two season's work, which have shown that the two sites of Billa and Gawra afford stratified sources for the study of more than four millennia of North Mesopotamian history, beginning with neolithic and extending down to Hellenistic times. Gawra is by far the older site. The occupation of Billa did not begin until Gawra had been occupied for a period of time represented by fourteen metres of occupation levels. From about 3000 B.C. down to the middle of the second millennium B.C. the two mounds show a virtually parallel course of development. Then, the Gawra site having become too narrow and high for further occupation, Billa carried on and was occupied for another millennium and a half. It would appear that Billa was first settled by an intrusive " chalice " folk—so-called from their most characteristic piece of pottery—and from that time on its history was that of a succession of invaders, all coming from the north or north-east.

Much is expected from the results of the expedition to Northern Mesopotamia, promoted by the British School of Archæology in Iraq (Gertrude Bell Memorial) under the direction of Mr. M. E. L. Mallowan, who was engaged in the investigation of the prehistoric strata of Nineveh with Dr. Campbell-Thompson's expedition in the previous year. The site attacked is situated at Arpachiyah, near Nineveh. Its choice had been determined by a preliminary reconnaissance made last year, in which surface finds yielded pottery, including the characteristic polychrome ware, comparable to that found in the earliest strata examined by Mr. Mallowan at Nineveh. It was thought that with little effort it should be possible on this site

to obtain material which would illustrate and extend our knowledge of the pre-diluvial culture found at Ur.

The results of the first half-season's work, reported in *The Times* of May 5, justify expectation. They confirm and extend the conclusions drawn from the American expeditions' excavations at Tepe Gawra and Tell Billa that Northern Mesopotamia was a meeting-place of peoples of varied origin in the neolithic and early chalcolithic ages Arpachiyah affords evidence of connection with Anatolia, Syria, Southern Mesopotamia, and through Persia with Baluchistan. On the top of the mound mud-brick dwellings of a humble character yielded pottery of the painted Ur and Tel el-Ubaid type, which at once carried the first settlement back to the fifth millennium B C, and determined its character as one of the earliest yet known in Mesopotamia. Evidence was found of two main periods of occupation, of which the later shows South Mesopotamian connections, and illustrates the infiltration of a new people, using a pottery differing in type from the delicate egg-shell painted pottery of the earlier period, and practising what is termed a method of fractional burial, which is compared with practice on the prehistoric site of Nál in Baluchistan. The use of the ox's head as motif suggests a special religious cult and female figurines point to affinities with the mother-goddess cult of Anatolia

At Ur, the joint expedition of the British Museum and the University Museum of Philadelphia under Mr C. L Woolley has made what is held to be the major discovery of the season in the identification of the *temenos* wall of the sacred area of the city, where stood the religious buildings of the Moon God, dating back to the twenty-third century B C. Previously it had not been known whether the great wall of mud-brick built by Nebuchadnezzar, and discovered by the expedition in 1922–23, was or was not the first erection of this character in the city. One of the main objectives of the past season's work was to dig for further traces of the buildings preceding Ur Engur's great tower, of which indications had been found in the previous season in the shape of an earlier ziggurat. The plan of the surroundings of this ziggurat has now been completed by the discovery of a temple of about 3000 B.C. lying against the south-east side of the upper terrace. This temple exhibits some remarkable features, not the least being the fact that in place of sanctuaries are furnace chambers, and it is Mr. Woolley's not unreasonable conjecture that in this temple were prepared the meals for the Moon God and lesser deities.

One of the most striking discoveries in Iraq during the past season is that of a tablet recording the names of Assyrian kings,

which was found by Dr. Frankfort in the temple of Nabu at Khorsabad, while excavating on behalf of the Oriental Institute of Chicago. The list begins in the third millennium B.C. and contains the names of kings earlier than any hitherto known. It is continued down to the eighth century B.C. and covers reigns of which the length had not previously been known.

Early Man in Britain.—Mr. J. Reid Moir's Presidential Address (1932) to the Prehistoric Society of East Anglia (*Proceedings*, vol. VII, Pt. 1) will be welcomed by a wider public who will be glad to know what he considers to be implied by his discoveries in the prehistory of East Anglia. He took as his subject "The Culture of Pliocene Man," but as a necessary preliminary discussed the age of the Suffolk Bone beds, from which his pre-Chellean implements have been derived, and their relation to the Corraline and Red Crag. He assigns the bone beds to the Pliocene and the Crag to the earliest phase of the Pleistocene, the first glaciation. It is evident, however, that much further research is urgently necessary before anything like a final solution of the difficulties attendant on the dating of the implements is attained. This Mr. Moir pointed out in discussing such points as the age of the implements of bone, and the striation on the flint implements after patination. In his view, these very difficulties indicate a much higher antiquity than their geological siting demands. His interpretation of the cultural evidence pointed in a like direction. For, he argued, it is evident that the sub-Red Crag implements differ markedly in their patination and are of widely differing ages. There are differences which are associated with different types of flaking; and successive races of man must have occupied the ancient land surface which existed in pre-Crag times. The makers of the sub-Red Crag implements had attained a high degree of skill in implement making, and they had developed an extensive and specialized array of implements and weapons—hand-axes, tranchets, scrapers, small push-planes, and burins—and therefore must have been living a life giving rise to needs of various kinds which these specialised implements helped to satisfy. They must have progressed a considerable degree along the path of human achievement. Thus as long ago as Pliocene days, mankind had already left its childhood's days far behind. Yet these Pliocene beds in which traces of man are found are made up of material of very different ages swept together, and their origin must be sought in deposits of a much remoter date.

Early Man in East Africa.—It would appear that something approaching finality is being attained in the geological dating of Oldoway Man. In a letter which appears in *Nature* of March 18,

Messrs. Leakey, Reck, Boswell and Solomon concur in regarding the skeleton as a burial in Bed II after the deposition of Beds III and IV but before Bed V had been deposited, at a time when Beds III and IV had been denuded and Bed II had thereby become a land surface. The red-coloured deposit overlying the "man site" and underlying Bed V, is regarded as a hill wash. An industry found on the old land surface and in the basal deposits of Bed V, of which Oldoway Man may very probably have been the maker, presents affinities with phase C of Upper Kenya Aurignacian. The comparison is further supported by the fact that the evidence from Gamble's Cave in Kenya shows that the men of this culture-stage buried their dead in the same contracted position as Oldoway Man.

If, however, this interpretation of the geological evidence at Oldoway brings "modern man" once more within the range of previously accepted views, it is otherwise with Dr. Leakey's further discoveries in Kenya. On March 18 and 19 a conference summoned by the Royal Anthropological Institute met at Cambridge to examine the evidence which he had obtained in his previous season's (1932) investigations at Kanjera and Kanam, two sites near Kendu at the north-east of Victoria Nyanza, an area well-known for its fossiliferous deposits. The material consisted of part of a femur and fragments of human skulls, fossil animal remains, many of extinct forms, and two stone industries, one a pebble industry and the other Chellean. Of the human bones two fragments were found in association with fossil animal remains and Chellean tools, while a fragment of human mandible from Kanam was found not far from a pre-Chellean stone implement. Of three groups of bones from Kanjera, one group formed a skull-cap and a second was reconstructed to form a skull.

Four sub-committees—geological, palæontological, anatomical and archæological—were appointed to consider and report on this evidence to the conference. It is to be noted that several members of these committees were personally acquainted with the sites. Briefly their findings may be summarised as follows: On the geological evidence it is not believed that the skeletal fragments can have been introduced into the calcareous deposits at a later date, and that the two fragments found *in situ* in fact belong to the original deposit; while the palæontological committee found that the Kanam jaw was associated with a fossil fauna which justified a reference to the lower Pleistocene and that the Kanjera fauna cannot be later than the middle Pleistocene. The anatomical committee was not unfavourable to the high antiquity of the human fragments, so far as could be determined by their condition, and saw no feature inconsistent with their

inclusion within the type of *homo sapiens*. It pointed out the absence of neanderthaloid characters, while marking the abnormal thickness of one of the skulls. Archæologically these human remains are associated with what may be termed a pre-Chellean and a Chellean industry which are equated with the European cultures of like character, through the Oldoway series, which may indeed be somewhat older than those with which they are comparable in Western Europe. The reports of the committees, which were commendably cautious in their phrasing, were adopted by the conference. As matters stand at present *homo sapiens* in Kenya, as represented by the Kanam jaw, is associated with a pebble industry which assigns it to the stage of Oldoway I, a stage earlier than that to which Oldoway Man was originally assigned—the later phases of Oldoway II. A full report of the findings of the conference will be found in *Nature*, April 1, 1933, and *Man*, April 1933, No. 66.

Further evidence bearing on the prehistory of East Africa comes from Uganda. Mr. E. J. Wayland records the discovery of some remarkable pits during building operations at Luzira near Port Bell on Lake Victoria. The presence of the pits was revealed through the recovery of a pottery human figure from the face of an artificial cliff, which led to further investigation. The pits were at first thought to be graves, but proved to be quite circular in horizontal section with no trace of a burial. Below strata of soil and red earth going down from 5 to 10 feet was a stratum of quartz rubble varying in depth from place to place from about an inch up to about a foot. The pits intruded downwards into the red soil and in one case into the rubble. They contained fragments of pottery and a number of fragments of pottery figures. The pits had evidently been refuse-tips and were relatively modern, though the figures in certain respects are unique. The rubble was found to contain artefacts belonging to two groups, the one being contemporaneous, the other derived. The latter were represented by a *coup de poing* of Acheulean affinities. Mr. Miles C. Burkitt, who reports on these industries, regards them as having affinities with those from a cave in the Kafue district of Northern Rhodesia where a *coup de poing* level is followed by rough tools, discs, scrapers, etc., resembling those found in Uganda (see *Man*, Feb. 1933, No. 29). Messrs. Wayland and Burkitt also report (*J. R. Anthrop. Inst.*, vol. LXII, Pt. 2) on a Stone Age culture discovered by the former at Magosi in Uganda. The site, evidently a habitation site, is situated by the side of what had once been a water cistern at the base of a granitic rock on the saddle of some bold hills. In the filling of the cistern some 11 feet of archæological deposits were discovered, the archæo-

logical remains being of two distinct types of industry, one microlithic and the other approaching the Still Bay point of South Africa. Mr. Burkitt in an acute analysis of these industries and their affinities points out that neither in Kenya nor in South Africa do the pygmy industry known as Wilton and the Still Bay industry occur in association, the latter being earlier than the Wilton ; and whereas the Wilton is neanthropic, it has been proved that the Still Bay is the product of a contact of an African Middle Stone Age people with a neanthropic race. He also points out that although the Magosi microlithic industry bears a closer resemblance to Wilton than the pre-Wilton microliths of Kenya, it is on the whole more archaic in appearance. He therefore suggests that at Magosi we have the existence side by side of a microlithic industry older than Wilton and a Still Bay industry which elsewhere is older than Wilton ; and further that Uganda may be the area in which took place the fusion between Still Bay and a neanthropic race, producing a proto-Wilton industry which migrated south and developed the true Wilton.

NOTES

The Gegenschein or Counterglow (A. H.)

The Gegenschein was discovered over 75 years ago but the first thorough photometric examination of it has just been completed at the Yerkes Observatory (see "Photometry of the Gegenschein," C. T. Elvey, *Astro. J.*, vol. LXXVII, p. 56 (1933)). The object consists of a luminous patch (barely visible to the naked eye save under very good conditions) and it is, apparently, simply a local enhancement of the zodiacal light situated directly opposite to the position in the sky occupied by the sun. The method adopted by Elvey involves the use of a photoelectric cell in conjunction with the Yerkes 40-inch refracting telescope. The telescope is traversed over the region of the sky in question and the response of the cell is noted. In this manner a map, resembling a contour map, can be built up which (after suitable correction has been made for illumination arising in the atmosphere, and for scattering in the atmosphere from terrestrial lights, the moon, etc.) gives the distribution of light from the area of the Gegenschein.

The investigation shows the shape of the counterglow to be, roughly, that of an ellipse whose minor axis may extend over 26°, the major over 35°, although the dimensions vary markedly from time to time. The integrated intensity is equal to that of a star of the $-0{\cdot}28$ magnitude, but this radiation comes from a very considerable area, hence at the centre of the luminous area (the brightest spot) the intensity per square degree is merely equivalent to that of a star magnitude 6·2, a star which would be invisible to the naked eye except under extraordinarily good seeing conditions.

It is generally believed that the zodiacal light is merely sunlight reflected from innumerable small particles occupying a lens shaped region which extends well out beyond the earth's orbit. The local enhancement of this light which forms the Gegenschein has been accounted for in two ways. The first suggestion is that the increased brightness is due to the individual particles being seen at full phase, whilst the other suggestion postulates a concentration of the particles due to the combined attractions of the sun and earth on a line

through these bodies and about 10^6 miles outside the orbit of the earth. Probably each explanation is partially correct.

The Discoveries of Charles Wilkes (J. N. L. B.)

In a valuable paper contributed to the *Geographical Review* for October 1932, Professor W. H. Hobbs re-states the claims of the American explorer, Charles Wilkes, to have discovered the Antarctic continent and deals in a vigorous manner with those who have thrown doubt on the accuracy of some of the work of the explorer. Although his discoveries were the cause of bitter controversy in the United States, Wilkes received due recognition in England when the Royal Geographical Society awarded him their Founder's Medal in 1847. This event coincided in point of time with the earliest English criticism of his work, that of Ross, who seems to have been ungenerous in his remarks and whose hasty judgment was accepted by some later writers. But it cannot be said that all condemned Wilkes; and in the standard British work on Antarctic Exploration, *The Siege of the South Pole* by Dr. H. R. Mill, Wilkes receives due credit for his work. More recent exploration—particularly the expeditions of Sir Douglas Mawson—has shown that some of the lands seen by Wilkes do not exist in the positions shown by him on his chart. How great the discrepancies are can be seen from the excellent map which accompanies this paper.

Professor Hobbs points out the difficulties of observation in Polar regions and lays stress on the exceptional conditions of visibility; and he believes that "in the clear air occasionally met with in such regions and raised by the mirage so common there" land at least 130 miles distant was seen by Wilkes and marked on his chart as 20 miles away. This is of course a matter incapable of proof; and one cannot resist the feeling that in trying to prove Wilkes right in every particular Professor Hobbs carries his argument too far. It is rare for the pioneer to be always right. Scott showed that Ross, who had a much better equipped party than Wilkes, made considerable errors; Sir Douglas Mawson has shown that he himself has been wrong; and taking everything into consideration the probabilities are that Wilkes too made mistakes. Certainly the map of Mawson's land expedition under Madigan does not seem to confirm the appearance of Cape Hudson as illustrated by Wilkes, whose drawing is reproduced by Professor Hobbs. It cannot be said that Wilkes's work stands or falls by these details. No one has paid higher tribute to his general achievements than Sir Douglas Mawson, who has also stated that he steamed west for a day along

the coast seen by D'Urville and Wilkes in 1840 and traced the land farther but could not follow it. There can be no doubt as to the reality of Wilkes's most important discovery, and with that of his claim to recognition.

At the same time Professor Hobbs raises the important question of the names given to parts of the Antarctic coast. When a few scattered pieces of coastline were all that was known of the Antarctic continent the problem was comparatively simple, but the gradual linking together of that coastline and the discovery of much new land has complicated the whole question. Hence the long stretch of "Wilkes Land" over the map has been contracted and his name given by Mawson to a part of the coast which in Mawson's opinion Wilkes did not see! Professor Hobbs reproduces parts of five maps drawn between 1841 and 1854 to illustrate the early usage, and shows how the later practice has departed from that, in the hope that a full presentation of the evidence will "point the way to a satisfactory solution."

A New Method of Amplification (S. K. L.)

Hitherto, valve amplifiers fed from battery supplies have been strictly limited in the acoustic power output owing to the necessity for economy in current consumption from the high-tension battery. In the conventional form of amplifier, the output valve passes a steady current when no signal is received, and this current is modulated equally above and below this value when a signal is admitted. The drain on the battery therefore continues uninterrupted.

A new principle which avoids this waste of current is described by E. Y. Robinson in *The Wireless World* for January 6, 1933. This method, known as quiescent push-pull amplification, has opened up a new era in battery-fed set design. Manufacturers have already introduced special equipment to meet the demands of the public. Whereas previously the battery set could feed only a small loud speaker, by the new method it can now compete with the mains-operated amplifier and radio gramophone. For instance, a power output of 1·3 watts is now obtainable with a total H.T. consumption of 6 milliamps at 120 volts.

In quiescent push-pull amplification, two pentode valves are used: one valve amplifies one half-cycle, whilst the other valve is rendered inoperative by a high value of grid bias, and during the succeeding half-cycle, the functions of the valves are interchanged. The currents from the two valves are combined in the output transformer to provide an alternating current for the loud speaker. The current through either valve when it is inoperative is negligibly

small. When no signal is received, both valves are inoperative, and the current rises only when modulation occurs. Herein lies the economy, for the average modulation of a broadcast signal is low (only 15–20 per cent.) and the idle time is considerable. Naturally, the current consumption depends on the type of programme. The success of the system depends largely on the correct design of the output transformer, since quite heavy peak currents may occur in either valve whilst the other is idle. This requirement calls for a transformer with a larger core than usual Other special features of this system are a high resistance in the common lead from the input transformer secondary to prevent the generation of parasitic oscillations which give rise to bad distortion of loud signals, and a resistance across the input transformer primary to prevent damage to the valves by high voltage surges. As is usual in pentode circuits, the output transformer should be shunted by a resistance-capacity filter to ensure a good frequency characteristic Moving-iron loud speakers are not suited to this circuit on account of their high impedance at high frequencies moving-coil speakers are quite suitable.

To illustrate the economy of the new method, the H.T. current consumption at 120 volts of output valves required for 1·3 watts output has been compared · for a triode a current of 55 milliamps is required, for a high-efficiency pentode 24 milliamps, and for pentodes in quiescent push-pull 6–7 milliamps

The Bulletins of the Imperial Agricultural Bureau (T. H.)

Biological Abstracts is one of the most valuable of post-war institutions in scientific literature. By means of references and serviceable abstracts it introduces a vast field of literature to, and thus encourages a catholicity of taste in, English-speaking biologists. Another and equally valuable service, which is complementary to that of *Biological Abstracts*, has recently been provided by the bulletins of the Imperial Agricultural Bureau in soil science, animal nutrition, animal health, agricultural parasitology, animal genetics, plant genetics and fruit production. One of these, the *Veterinary Bulletin*, is published by the Imperial Bureau of Animal Health from its offices in the Ministry of Agriculture and Fisheries' laboratories at Weybridge, Surrey. The *Veterinary Bulletin* is edited by Mr. W. A. Pool, M.R.C.V.S., a former director of the Moredum Research Institute in Scotland, assisted by Mr. J. T. Edwards, M.R.C.V.S. The first annual volume was published in 1931 ; its monthly issues now include adequate and informative reviews of the literature on bacteriology, immunology, pathology, physiology, therapeutics and public health as applied to animals. Authors and subject indices

are provided for each monthly number and for each volume. The annual subscription is £2.

The *Veterinary Bulletin* has already secured a wide circulation among veterinary research workers throughout the British Empire; its acceptance by biologists, other than veterinary, should be ensured by the high quality of its service.

The Opening of the Halley Stewart Laboratories (H. T. F.)

On May 4 Lord Rutherford formally opened the new laboratories recently acquired by King's College through the generosity of the Halley Stewart Trust. The laboratories are situated in Chesterford Gardens, Hampstead, in a quiet neighbourhood remote from the disturbances which are inevitable in a large city and which make research in some branches of Physics impossible. They are an extension of the Physics Department of the College and will be used entirely for research under the directorship of the Wheatstone Professor of Physics. At present the chair is occupied by Professor E. V. Appleton, F.R.S , and the main work in the new laboratories will, under his direction, be the study of the electrical conditions prevailing in the upper atmosphere. The work already accomplished has shown the importance of the results which Appleton's experiments reveal and the fertility of his methods. The gift of the Halley Stewart Trust comes almost miraculously at a moment when the greater refinements of new work in this extending field demand a less disturbed atmosphere than that which surrounds and pervades the laboratories in the Strand.

The verification of the existence of the refracting layer associated with the names of Heaviside and Kennelly, the discovery of the second refracting layer—the Appleton layer—and the discovery that radio waves are polarized after refraction, are the most spectacular of the results obtained. These results are of the greatest importance to physicists and radio-engineers alike, but the new field still awaits detailed study and calls for prolonged investigation of phenomena of importance, at least, to the physicist.

A research school has already been established under almost ideal conditions for this work and students are actively engaged upon it. The special problems, on which they are experimenting, include the study of the cause of the ionisation in this upper region, the nature of the ionised particles, the influence of magnetic storms on the ionisation and the recombination of ions in this region.

Another important question is the relation between the upper atmospheric conditions and terrestrial magnetism. The work consists in sending up radio-frequency waves, which return with informa-

tion about the region traversed. Another radiation, which traverses the same region, is cosmic radiation and the study of it is an appropriate companion undertaking. Research on this subject is also proceeding in the department. This radiation is, of course, not a special messenger, but it is not inconceivable that like radio-waves, it may carry some impress of the path traversed.

The other work in progress in the laboratories comes under the title of Radioactivity. It is under the direction of Dr. H. T. Flint and has arisen from work on the establishment of an accurate international unit of dosage in radium therapy. A number of physical problems requiring new methods of measurement of the intensity of gamma rays and investigations of absorption by various materials have arisen and already students are engaged on them. Finally it is hoped to make use of the radioactive material available to extend the work on nuclear Physics, which has already begun in the Physics Department of the College

Miscellanea

The names of the candidates for election into the Royal Society admitted this year are as follows : —Mr P. M. S. Blackett, physicist, Cambridge ; Professor J. B Collip, biochemist, McGill ; Colonel R. E. B. Crompton, electrical engineer ; Professor H. M. Dawson, physical chemist, Leeds ; Dr. A. T. Doodson, mathematician, Liverpool Observatory and Tidal Institute ; Dr. H. J. Gough, engineer, National Physical Laboratory ; Mr. J Hammond, physiologist, Cambridge ; Dr. G. M. Holmes, physician, National Hospital for Nervous Diseases, London ; Dr H. King, chemist, National Institute for Medical Research, London ; Professor J. E. Lennard-Jones, mathematical physicist, Cambridge , Professor J. W. McLeod, bacteriologist, Leeds ; Dr. A. S. Parkes, physiologist, London ; Professor E. J. Salisbury, botanist, London ; Dr. B. Smith, geologist, H.M. Geological Survey ; Dr. W. R. Thompson, entomologist, London ; Professor A. M. Tyndall, physicist, Bristol ; Professor J. H. M. Wedderburn, mathematician, Princeton University.

H.M. The King has approved of the following awards by the Royal Geographical Society : Founder's medal to Mr. J. M. Wordie for his explorations in the Weddell Sea ; Patron's medal to Professor Erich von Drygalski for his researches in glaciology in north and south polar regions.

We have noted with great regret the announcements of the death of the following well-known men of science during the past

quarter: The Duke of Abruzzi, explorer; Lt.-Col. A. W. Alcock, F.R.S., professor of anthropology in the London School of Hygiene and Tropical Medicine; Professor J. van Baren of Wageningen, soil mineralogist; Professor G. C. Bourne, F.R.S., emeritus professor of zoology and comparative anatomy in the University of Oxford; Mr. F. B. Burch of the Metropolitan Vickers Co, best known for his work on the 30-kilowatt valve constructed by that company; Professor C. Correns, first director of the Kaiser Wilhelm Institute for Biological Research, Berlin; Professor E. W. Hobson, F.R.S., formerly Sadleirian professor of pure mathematics in the University of Cambridge; Dr A. Rée, colour chemist, Manchester; Professor F. Rinne, crystallographer, Leipzig; Professor J. Schmidt, oceanographer, Copenhagen; Professor E C. Starks, ichthyologist, Stanford University; Professor J. Millar Thomson, formerly head of the chemical department, King's College, London; Professor W. C. Unwin, F.R.S., emeritus professor of engineering in the City and Guilds Technical College, London, Professor M. Wolf, astronomer, Heidelberg.

The *Annual Report* of the Department for Scientific and Industrial Research for 1932 (H M. Stationery Office, price 3*s*. net) shows that the valuable assistance which the investigations conducted by, or under the auspices of, the Department is giving to industry, is receiving material recognition in the shape of increased support. The Electrical Research Association has consolidated its position relative to the supply undertakings and now derives approximately one half of its industrial income from this source. The Non-Ferrous Metals Research Association has secured the membership of the majority of the lead manufacturers in the country. An appeal from the Refractories Research Association for a much greater degree of support from the refractory material makers and the using industries has met with a gratifying response, particularly from some of the larger units in the gas industry. The Cotton Industry Research Association already comprises in its membership practically all the firms in the spinning and manufacturing sections since these contribute to its support through their respective trade associations. The Association is demonstrating to its members the practical value of its operations by sending members of its liaison staff out to mills and works (over 2,000 such visits were made during the year 1930–31) and by its readiness to give scientific advice on problems arising in the course of routine operations. A similar policy is adopted by most other Research Associations, but the Cotton Industry Research Association is notable in this respect, for it has been called upon

to carry out over 1,100 investigations arising from 1,500 queries of this nature received during the year.

The question of a compulsory levy on firms engaged in a particular industry in the interests of its Research Association has been considered, but general opinion seemed to indicate that there is little to be gained by compelling firms to contribute if they were unwilling to do so. The proposal, now before the House of Lords, to compel contributions from the rubber industry in support of the Rubber Research Association may perhaps be designed as a further test of this opinion.

An experiment carried out by the Lubricants Committee is of considerable interest to motorists and users of internal combustion engines in general. A sample of used engine oil which had been running for 8,000 miles in a car was tested and compared with a new sample of the same brand of oil and it was found that although the used sample gave much lower seizing temperatures than the new sample when first run in the machine, its performance rapidly improved until it was practically equal to the new The temporary deterioration of the oil appeared to be due chiefly to the water which had accumulated during the time it had run in the engine. This opens up a fresh field for investigation, for if deterioration is due to this cause alone, it appears to be quite feasible to provide means of purification from water on the engine, which may mean the reduction of oil consumption to one-eighth of the amount at present used.

Continuing their work on the radioactivity of samarium Hevesy and Pahl report (*Nature*, March 25) that it emits 75 α-particles per sec. per gm. and that these particles have a range of $1{\cdot}1_3$ cm. in air at 15° C. and 76 cm. pressure. The number emitted per gm. is based on the assumption that the radioactive properties of the element are due to the main isotope : while this is yet uncertain there is at least evidence that it is not due to an isotope present only in small amounts. Hevesy and Pahl also observed pronounced radioactivity in lanthanum and neodymium, but were able to remove it by " the usual reactions of radiochemistry " whence they concluded that in these cases the radioactivity is due to the presence of known radioactive elements. Libby and Latimer (*J. Amer. Chem. Soc.*) confirmed the discovery that samarium is radioactive and found that lanthanum and neodymium emit β-rays. They pointed out, however, that this emission might be due to impurities. Gadolinium showed no signs of radioactivity.

Paneth and Gunther stated in a letter to *Nature* (May 6) that they have applied the method they have devised for the measurement

of minute quantities of helium to ascertain the amount of helium obtained when various substances are bombarded with unfiltered rays from thorium B and thorium C (*i.e.* α, β and γ rays and recoil atoms). For many substances (*e.g.* water and mercury) the amount of helium corresponded, within 10 per cent., to the number of α-particles shot in; but in the case of certain hydrocarbons (paraffin, palmitic acid and diphenyl) surpluses up to 100 per cent. were obtained. This is an entirely new phenomenon requiring further investigation and confirmation

Two important series of measurements of vapour pressure are described in recent numbers of the *Journal of Research* of the Bureau of Standards, U.S A. The February issue contains a paper by Osborne, Stimson, Fiock and Ginnings on the pressure of saturated water vapour over the range 100° C. to 374° C. (the critical temperature) and, in March, Meyers and Van Dusen described their work on the vapour pressure of liquid and solid carbon-dioxide. In both these investigations the static method was employed, the vapour pressure being balanced against a dead-load on a piston working in a cylinder filled with oil. The details of Osborne's experiments are of unusual interest and reference to the paper is recommended. Measurements were made at thirty-eight temperatures and values of the vapour pressure for each degree centigrade between 100° C. and 374° C. were worked out from an empirical formula [1] using one set of constants for the range 100°–275° C. and another set from 275° C. to the critical temperature. The critical pressure was found to be 217·96 atmospheres ($220{\cdot}85 \times 10^6$ dynes $cm.^{-2}$) and it was estimated that, except in the critical region, the results are correct to 3 parts in 10,000.

Meyers and Van Dusen covered the range − 210° C. to 31° C. and considered that their values for the saturation pressure over liquid carbon-dioxide are correct to 1 part in 10,000. The critical data are 31·00° C. and 72·80 atmospheres ($73{\cdot}76 \times 10^6$ dynes $cm.^{-2}$); the triple point is − 56·60° C., $5{\cdot}180 \times 10^6$ dynes $cm.^{-2}$.

Among other interesting papers in these two numbers of the *Journal of Research* are two by Caldwell and by Roeser and Wensel on the thermoelectric properties of platinum platinium-rhodium thermocouples and an account of an extensive investigation of the temperature coefficients of the moduli of elasticity of various metals by Keulegan and Houseman. Elinvar has the smallest observed

[1] $T\log_{10}p = aT + b + cx^2 + dx^5 + ex^6$ where $x = \left(\dfrac{T^2}{298{,}000} - 1\right)$ and $T = (273{\cdot}1 + t)°$ C. !

temperature coefficients (rigidity : $\frac{1}{N}\frac{dN}{d\theta} = -7{\cdot}2 \times 10^{-5}$ per deg. C., Young's modulus : $\frac{1}{Y}\frac{dY}{d\theta} = -6{\cdot}6 \times 10^{-5}$ per deg. C. for the range $-50°$ C. to $+50°$ C.) while duralumin has the largest ($-55{\cdot}1 \times 10^{-5}$ and $-58{\cdot}3 \times 10^{-5}$ respectively). The values for tungsten are nearly as small as those for elinvar while the maximum shear stress for tungsten (33,100 lb. wt in.$^{-2}$) is more than three times as great as that of any other metal investigated (For oil-tempered piano wire it is 10,900 lb wt in.$^{-2}$.)

The December number of the *Journal* contains a description of a multi-range potentiometer designed by Brooks and Spinks in which special attention has been given to the elimination of thermoelectric effects at the galvanometer keys. In particular there is a full description of an enclosed key with an "astatic" arrangement of contacts arranged so that the contact e.m.f.'s oppose and cancel each other.

ESSAY-REVIEW

A NEW THEORY OF ANIMAL COLOURATION. By E. S. RUSSELL. Being a review of **The Meaning of Animal Colour and Adornment,** by MAJOR R. W G. HINGSTON. [Pp. 411, with 40 figures.] (London : Edward Arnold & Co , 1933. Price 18*s*. net.)

THE sub-title of this book describes it as offering " a new explanation of the colours, adornments and courtships of animals, their songs, moults, extravagant weapons, the differences between their sexes, the manner of formation of their geographical varieties, and other allied problems."

The fundamental theory put forward to account for all these things is simple enough, and it is rammed home with a Darwinian wealth of natural history knowledge—as one would expect from a naturalist of Major Hingston's experience and calibre. It is that there is throughout the animal kingdom a conflict in the individual between two emotions, the emotion of anger and the emotion of fear. These two conflicting emotions find their expression in many ways— in behaviour, in colour pattern, even in structure.

So expressed, the theory sounds somewhat fantastic, and there is undoubtedly an element of poetic and philosophical fantasy inherent in it, as there is in Bergson's poem of evolution, *L'Évolution créatrice* Thus Hingston writes on the last page of his book, " All life is comparable to a growing tree with its great trunk, main limbs, smaller branches and twigs. . . . The whole tree of life is growing and spreading by one internal developing urge which for want of a better term we must call the emotional content of the tree. The channels along which that growth is proceeding are the many and varied parts of the machinery by which the emotional content is exhibited. External influences are advancing or retarding this growth, and the growth itself is predestined to a natural termination. But all through, in every part of the structure, trunk, limbs, branches, twigs and shoots, this growth is generated by one common impulse inherent in the tree of life itself " (p. 398). From which one sees that Hingston is a Bergsonian *sans le savoir*. I have thought it right to bring out at the beginning the trans-

cendental basis of Hingston's theory, as I understand it, but it would be unfair to emphasise it too much. Let us consider instead some part of the great mass of sober evidence which Hingston adduces in favour of his view, and let us take first his explanation of animal colouration.

We know that many animals exhibit protective colouration, which helps them to elude their enemies or to creep stealthily upon their prey. But there are many exceptions to this rule; many animals, especially of the male sex, show bright and conspicuous colours, which are displayed particularly in emotional situations. There is in many species a combination of these two types of colouration—concealing colouration, the badge of fear, and striking colouration, which according to Hingston is the insignia or expression of anger, rivalry and rage. It is Hingston's view that conspicuous colouration is meant to strike terror into an opponent, or rival or prey. It is in attack, or in threatened attack, that these colours are displayed; at other times they may be completely overlaid and hidden by concealing colouration.

Take for instance the lion. This is a light khaki-coloured animal whose ground colour is undoubtedly concealing and enables it to approach its prey without disturbing it. But there are three areas where the tawny colour is replaced by brown or black; these are the mane, the tail-tuft and the patch on the back of the ear. Now when the lion is excited and about to charge it erects the mane, raises and lashes the tail, and draws back the ears, thus displaying these dark-coloured areas. Hingston's theory is that the exposure of these dark colours is an expression of the emotion of anger and has the effect of intimidating the adversary or the prey. "When he stands before his rival fully enraged, his black ear-patches look directly forward, his dark mane is widely expanded, his tail-brush is swishing over his back. In other words, he has made himself as conspicuous as the mechanism at his disposal permits. As his anger diminishes so does his conspicuousness; his ears rotate and hide their black surfaces, his mane retracts behind the tawny fringe, his tail-swishings cease and the appendage is lowered. His conspicuous pattern, as it were, shrinks back into the shelter of his concealing coat" (p. 16). There is in the lion a "colour-conflict" between the concealing pattern and the display or intimidating pattern.

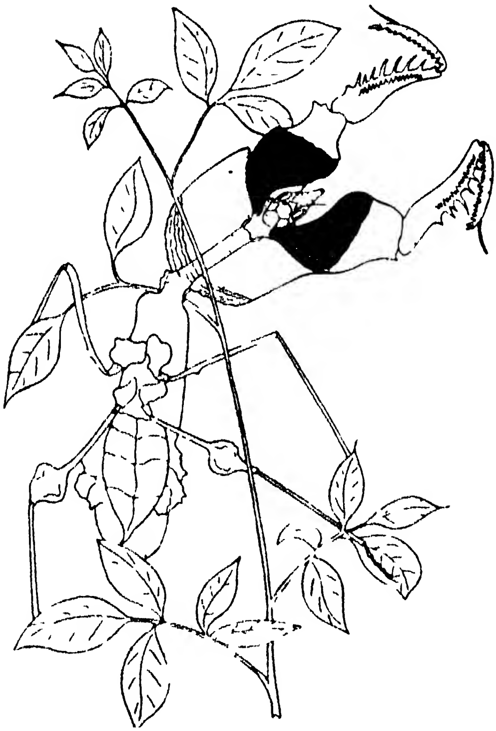
Hingston illustrates this principle throughout the whole animal kingdom, with special reference to vertebrates and insects. The use of startling colours or bold patterns is exemplified also by savage man, who uses them to strike terror to the hearts of his

foe. In comparatively modern times, we find the same principle shown by the scarlet coat of the soldier, which is now replaced by the concealing colouration of khaki or field grey. Let us take a couple of examples from insects, in further illustration of the principle. In Lasiocampid caterpillars there are two transverse slits behind the head; when the caterpillar is touched, two tufts of brightly coloured hair are shot out suddenly, to alarm and startle the aggressor. There can be no doubt, says Hingston, that these tufts are meant to intimidate, and are successful in intimidating, lizards and birds. A similar mechanism exists in the caterpillars of swallow-tail butterflies, which shoot out two fleshy clubs when alarmed; these clubs exhale a pungent odour. "But it is mantids that make the most intimidating gestures and bravest show of threatening colour. A fine example is the African *Idolum diabolicum*. When disturbed, it stands erect, faces the enemy, and opens its front legs like outstretched arms This act exposes a mass of colour—red-brown, purple-brown, green-white, dark green —which tints are ordinarily kept concealed Moreover, the exhibition is certainly frightening Dr. Carpenter tells us that it frightened him; and he saw a monkey back away from it, the mantis having saved itself by the terrifying attitude" (p. 218). Hingston's Fig. 34 is reproduced opposite in illustration of this remarkable case.

Intimidating colour or pattern is displayed not only to frighten off enemies and to strike terror into the prey, it is used also in male rivalry, whether this takes the form of actual fighting or of psychological conflict, as in the mock battles of male butterflies. Extravagant colours, and extravagant weapons, which are characteristic particularly of male animals, go with pugnacity and the "trailing of the coat" before rival males. Sexual display, so-called courtship, is not intended to charm the female, as Darwin believed, but it is (1) an expression of emotion, and (2) a threat to rivals. The gestures made before the female are the same as those made in front of a rival male. Hingston's Chapter 14 contains a full and able criticism of the theory of sexual selection, but into this and his general interpretation of sex and sex behaviour we cannot enter here. Suffice it to say that he discerns a strong element of hostility in the sexual urge of the male.

This is only a bare outline of Hingston's main theory. As already stated, he supports his theory with a vast amount of example, and the book is a treasure house of natural history fact. As to whether Hingston has proved his main points, opinions will vary. He has certainly brought out a new factor, which is of undoubted importance for the explanation of animal colour and

adornment, and his book should stimulate research with the object of testing his views. Clearly much further evidence is required that conspicuous colouration has the intimidating value that Hingston ascribes to it, and it is most desirable that this should be acquired by experiment. One has the impression that there is too much arguing on probabilities and presumed general principles, just as there is in Darwin's own works. Teleology at its worst is shown in the following passage. "The Greenland ptarmigan has three moults in the year, and one naturally asks how this is ex-



plained. The bird is (1) pure white in the winter months, (2) black and yellow in the spring-summer months, (3) mottled grey in the summer months. . . . Why is this? It is due to the fact that the Arctic environment itself undergoes a colour change, and the bird has to assume, in addition to its fighting coat, two other concealing garbs in order to match two different environments. It is pure white in winter because white best conceals it on winter snow. It moults in spring into a conspicuous black-yellow which is its uniform for the fighting season. At the end of that season, like other birds, it moults into a concealing pattern, but at the time

of this moult the snow has not appeared; the country is covered in grey heath, hence the bird must assume a grey pattern that will suitably match the heath. In August, however, the snow begins to come and the country changes from grey to white. Hence the bird must make a third change in plumage; it must throw off the concealing grey and put on the concealing white" (p. 302). It is quite legitimate to call attention to the adaptive nature of the changes in plumage, but it is not correct to account for their occurrence by the fact that they are necessary, and this remains true even though it is assumed that these adaptive colour changes have arisen by a process of natural selection. Darwin himself was not guiltless of this teleological form of reasoning

It seems also, even to a sympathetic reader, that Hingston presses his theory too far. Thus the extravagant tusks and horns of some mammals are explained as being psychological weapons intended to give them dominance over their fellows through appearance alone. So too the excessive nipper of the fiddler crab is regarded as an organ of threat. One would like more definite evidence that these weapons do actually function as supposed, and if the explanation of function is correct this does not necessarily explain the mode of origin. There are such things as laws of growth, both ontogenetic and phyletic.

One would further like to see Hingston's ideas about the importance of emotion linked up with the facts of physiology. Thus he very rightly points out, especially apropos of birds, that emotional activity and bright colouration are associated with the mating season, and that in birds the mating plumage is usually replaced in the autumn moult by a duller pattern of a more concealing nature, as the fires of love die out. But underlying both the emotional expression in behaviour and the heightened and altered colouration there are profound physiological changes affecting the reproductive organs and through them much of the rest of the body. Instead of speaking rather vaguely of plumage change as the outward expression of emotion change (p. 300) would it not be better to consider in their complex interrelations with outward expression the fundamental physiological processes which lie at their root? Perhaps there is, at the bottom of sex differentiation and its expressions, some fundamental metabolic difference, some heightening or intensification of metabolism in the male, especially conspicuous at the breeding season—as Thomson and Geddes have always maintained.

These are some of the criticisms which the book inevitably suggests. Now for some of its merits. Hingston is not one of

these biologists who can see nothing beyond their laboratory windows. He has collected his facts in direct contact with the richness and complexity of nature; he knows that animals are not merely physiological mechanisms ready to yield up their secrets to laboratory analysis; he appreciates the fundamental importance of studying them as active resourceful agents with their way to make in a difficult world. In his linking up of the study of colour and pattern with behaviour I see the chief merit—and a great one—of his book. Clearly colour and colour pattern are not things, as it were superimposed, upon a passive organism, they play a rôle in its life; they are used for its vital purposes, or rather it makes active use of them. Protective colouration, for example, is linked up with appropriate behaviour, immobility is just as important for the leaf butterfly as its detailed resemblance to a dried leaf. In the same way, conspicuous patterns, whatever their function may be, are only of value when they are displayed at the right moment by the appropriate activity of the animal.

There is a great field here for experiment—on the functional value and the actual worth (for survival) of colour pattern, whether concealing or conspicuous We know surprisingly little about the actual operation of natural selection upon supposedly concealing colouration, and our knowledge of the perceptions of animals generally is very fragmentary. We cannot assume without proof that they can perceive colour at all, and we are certainly not entitled to hold that they perceive elaborate patterns, unless there is definite experimental proof that they can. The field naturalist and the expert in animal psychology must here work hand in hand. We should gain by this association a much better knowledge of the perceptual worlds of animals, and a much clearer understanding of the biological value of animal colour and colour pattern.

REVIEWS

ASTRONOMY

Kosmos. By WILLEM DE SITTER. [Pp. xii + 138, with 12 portraits and plates and 11 figures.] (Cambridge, Mass.: Harvard University Press; London: Humphrey Milford, Oxford University Press, 1932. Price 9*s*. 6*d*. net.)

In November 1931 Prof. de Sitter was invited to give a course of six lectures at the Lowell Institute, Boston, Mass., on the "Development of our Insight into the Structure of the Universe," and, with a few additions, they are here printed substantially as they were delivered. It was naturally impossible to give a complete history of the subject, but the more important turning-points in the course of the evolution of our present-day theories have been carefully selected, explained and emphasised.

Attention is first directed to Aristarchus and Ptolemy, showing how the heliocentric conception of the former was temporarily discarded in favour of the complications of epicycles and excentrics. Then follow summaries of the contributions of Tycho, Kepler, Galileo and Newton, with a fuller description of the pioneer work of Herschel, the real founder of sidereal astronomy. The work of Kapteyn claims the whole of Chapter IV, and the rest of the book describes the latest ideas concerning the galactic and extra-galactic systems, and the nature of the universe as interpreted by relativity. Here the author can speak with authority, and his account, representing his own view of the scientific position at the time of writing in March 1932, commands both interest and respect, although, on his own confession, his conception of the universe will probably soon be superseded. The problem of the rate of expansion of the universe remains unsolved; it seems that the time necessary for the evolution of a star is much longer than the life of the universe! De Sitter is willing to accept the paradox, and to allow the "universe," regarded like the atom as a hypothesis, to have properties contradictory to those of a finite material structure. Meanwhile he stresses the importance to astronomers of patience and organised co-operation in their search after truth.

Everyone will not support the author's statement that Galileo owes his prominent place in history largely to his persecution, and that his work was much inferior to that of Kepler. It might also be suggested that rather undue prominence is given to the work of Kapteyn, whose conception of the galactic system is already, after a few brief years, completely out of date, and whose principal achievements were his introduction of statistical methods and his success in securing international co-operation for his "Plan of Selected Areas." The earlier attempt at such co-operation in the Astrographic Chart and Catalogue was not an unqualified success.

The book is written in interesting style, and is well printed. The only sign that the author is writing in a foreign language appears in very occasional unusual expressions such as "shrinked," "aversion of," and "Wega."

R. W. W.

The Expanding Universe. By SIR ARTHUR EDDINGTON, Plumian Professor of Astronomy in the University of Cambridge. [Pp. vii + 128, with 2 plates.] (Cambridge, at the University Press, 1933. Price 3*s*. 6*d*. net.)

THIS altogether delightful little book is based on addresses delivered to public audiences in the United States last autumn. It is divided into four chapters dealing respectively with the evidence for the recession of the galaxies, with spherical space, with some consequences of its expansion and with the author's theory connecting the radius of world curvature with the size of the hydrogen atom. Parts, at least, of the story will be familiar to most of our readers; some of it, indeed, the author has told in this country, *e.g.* in his Presidential Address to the Physical Society. Here however it is given leisurely as a connected whole and the last chapter contains the first account, intelligible to any but the elect, of the bold arguments which have led not merely to the law of expansion but to a numerical estimate of the number of protons and/or electrons (which is not certain) in the Universe.

Sir Arthur Eddington is not dogmatic. He believes whole-heartedly in his theory but is nevertheless willing to regard it as an adventure in ideas. Whether his readers follow him in all his journeyings or not it is at least certain that they will enjoy reading about them.

D. O. W.

PHYSICS

Müller-Pouillets Lehrbuch der Physik. 11 Auflage. Vierter Band, Dritter Teil. Elektrische Eigenschaften und Wirkungen der Elementarteilchen der Materie. [Pp. xviii + 828.] (Braunschweig: Friedr. Vieweg & Sohn, 1933. Price RM. 54 geh., 58 geb.)

IN SCIENCE PROGRESS, reviews of the first two parts of vol. IV of this excellent work have already appeared. We now have before us the third part, dealing with the electrical aspects of the properties of atoms and molecules. The treatment of modern magnetism will be given in the last part of the volume.

On the whole, the book now before us is likely to appeal even more strongly to the English reader than its predecessors have done. It is, of course, just as excellently printed and illustrated, but the arrangement of the material is so good and the treatment so thorough that all interested in modern physics will be well advised to consult it.

The book consists of an introduction and five sections. The first section is by Gerthsen of Giessen and Kossel of Danzig, and deals with the free electron, positive rays and the passage of corpuscular radiation through matter. This section has distinct pedagogic value, and the reviewer noted particularly the excellent plate of discharge phenomena in gases, the full description of the measurement of current through gases and of Brüche's Fadenstrahl experiments. It was felt, however, that the description of the measurement of e/m for an electron should have included some more modern methods. The discussion of the variation of the mass of an electron with

velocity is very good. In the portion devoted to an introduction to wave mechanics the experimental basis is extremely well set forth.

The chapter on positive rays includes an account of the work of Oliphant and a brief reference to that of Cockcroft and Walton. The beautiful positive ray parabolas photographed by Conrad and Eisenhut are reproduced, and a good summary of Wien's work is given.

The chapter on the passage of corpuscular radiation through matter forms a very comprehensive survey of the whole subject. It includes a section on the application of wave mechanics to this important problem, and a discussion of the atom form factor. It also includes a good description of Reichsanstalt apparatus for the measurement of X-ray dosage.

The reviewer was not so favourably impressed by the second section, on discharges in gases, contributed by Steenbeck of Berlin. It was felt that references to English contributions to the study of these phenomena are singularly inadequate and rather out of date The laws of similarity for glow discharges are rather well treated and there is a good discussion of "plasma" phenomena.

For the third section, on the electrical structure of the nucleus, contributed by Kirsch of Vienna and Teller of Göttingen, there can be nothing but praise, for it is very complete and up-to-date. It contains good discussions of the packing fraction and of the application of wave mechanics to the problems of nuclear structure. There is a section on the neutron, and on Heisenberg's model of the nucleus, which first appeared in 1932; usually, contributions since Easter 1931 are dealt with in footnotes.

The fourth section, contributed by Dunkel of Cologne and Wolf of Kiel, deals with the forces between atoms and molecules. It contains a very good analysis of Wierl's results on carbon tetrachloride and a full discussion of the work of Heitler and London. Indeed, this section is one of the most valuable in the whole book.

Wolf is also responsible for the fifth section This consists of two chapters on dielectric constants, the electrical polarisation of atoms and molecules and allied phenomena, and a chapter on pyro- and piezo-electricity. A good account of Debye's theory of dipoles is given, and the last two sections of the book can be strongly recommended to chemists as well as physicists. The final chapter on pyro- and piezo-electricity is the best account of both the theoretical and the experimental aspects of these phenomena that the reviewer has so far seen.

A very good index is provided; this book is strongly recommended to all teachers of advanced physics.

L. F. B.

Einführung in die theoretische Physik. Dritter Band, Erster Teil. Elektrodynamik und Optik. By DR. CLEMENS SCHAEFER, Professor of Physics in the University of Breslau. [Pp. viii + 918, with 235 figures in the text.] (Berlin and Leipzig: Walter de Gruyter & Co., 1932. Price RM. 37.50, geb. 40.)

AT a recent lecture in London a German professor likened Goethe's *Faust* to a cathedral, a monumental work in which many styles of architecture could plainly be seen, and, yet, in which the dignity and unity of the building as a whole was magnificently preserved. In perusing the first part of the third volume of this introduction to theoretical physics we are singularly

reminded of the above comparison, although the book before us corresponds to but one wing of the cathedral. It is sufficient however to permit us to visualise the beauty of the complete work, and to resolve upon becoming better acquainted with the two volumes which have already appeared.

It is impossible in a review of ordinary length to do justice to the book. How can we systematically mention the outstanding features of over nine hundred pages? It is only possible to mention a few of the points of interest which have given us particular pleasure.

The book is very well planned although it is developed along somewhat unusual lines. For the author starts with the fundamental theorems of electrostatics and magnetism and proceeds to the elaboration of Maxwell's equations, which serve him as the basis of his introduction to the theory of optics. Moreover, he takes into consideration in his theory of optics the whole range of electromagnetic vibrations from X-rays to wireless waves.

The author shows a very profound knowledge of the subject-matter in this book. His treatment is no ordinary, undistinguished description of theorem upon theorem, but shows that he has a remarkable appreciation of the difficulties which the average student encounters, and that he has spared no pains in his attempt to lessen these difficulties. He most certainly gives us the impression that he has not omitted a single point of theoretical interest because its explanation is difficult He shows a lively appreciation of the importance of units and dimensions and of the order of magnitude of the physical constants which occur in his work We particularly appreciated the directness of his methods of dealing with the problems of circuits containing self-inductance and capacity, and his treatment of the propagation of electromagnetic waves along wires is extraordinarily good.

The chapters on optics are beautifully illustrated. Following the plan of the book, the successive chapters deal respectively with the optics of transparent media, the optical behaviour of metals, the optics of crystals, interference and diffraction. Passing to the phenomena of dispersion the fundamental equations of the Lorentz theory of electrons are developed in a further chapter. Then a chapter is devoted to the theory of black body radiation, and, finally, the book closes with a chapter on the theory of relativity, a fitting close to this excellent treatise on classical physics.

We hope that this book will reach a wide circle of readers. It is true that the current rate of exchange is against it, but its price is really so reasonable that we hope that its sale will not be unduly reduced by exchange problems. We look forward to the appearance of the second portion of this volume which is to deal with the theories of the atom and the quantum theory.

L. F. B.

Atmospheric Electricity. By B. F. J. Schonland, O.B.E., M.A., Ph.D., Senior Lecturer and Fellow in Physics at the University of Cape Town. [Pp. vii + 100, with 25 diagrams.] Methuen's Monographs on Physical Subjects. (London: Methuen & Co. Ltd., 1932. Price 2*s*. 6*d*. net.)

Of all the branches of electricity and magnetism of which mankind has collected reliable information, surely none has been more neglected by English writers than that of atmospheric electricity. Previous to Dr. Schonlands'

excellent little monograph no book exclusively devoted to this branch of physics has appeared in English, and our students have been obliged to refer to French and German books, which, however excellent, present language difficulties. The reason for this neglect is not obvious, for some of the most important original work has been done in English.

Dr. Schonland's monograph goes as far as one can possibly expect of a volume so strictly limited in price and size to remove this reproach upon our literature, and its appearance should do much to encourage a more intense study of atmospheric electricity. The reviewer has for many years impressed upon students that in atmospheric electricity they had a field in which valuable research might be done, even at schools where the equipment was not of the best.

The author has given a very pleasant account of the ionisation of the atmosphere, of cosmic radiation, of electric fields and currents in the atmosphere, and a good outline of the processes which are supposed to occur in thunder-clouds. His descriptions of apparatus and experimental procedure will be of great help to students and his lists of references most valuable. The reviewer only wishes that the author had found space for a description of mechanical methods of measuring potential gradients suitable for use with aircraft, and a more adequate account of the errors to which aircraft measurements are exposed.

We hope that the book will be very widely read.

L. F. B.

CHEMISTRY

An Introduction to Organic Chemistry. By Roger J. Williams. 2nd Edition. [Pp. 585.] (London: Chapman & Hall, Ltd., 1932. Price 21*s*. net.)

As an elementary textbook of organic chemistry this volume by an American author is adequate, but the unusual " publisher's puff " incorporated before the author's preface suggests it should be subject to more rigid examination. This runs as follows:—" To the Student who uses this Textbook: This textbook represents many years of learning and experience on the part of the author. It does not treat of an ephemeral subject, but one which, since you are studying it in college, you must feel will have a use to you in your future life. Unquestionably you will many times in later life wish to refer to specific details and facts about the subject which this book covers and which you may forget. How better could you find this information than in the textbook which you have studied from cover to cover? Retain it for your reference library. You will use it many times in the future. The Publishers."

Here are two strange conceptions: first that a subject studied at college is of necessity one that will be " useful " in after life apart from its educative value, and secondly that an elementary textbook is the most suitable work of reference.

The present volume having been reprinted several times and now appearing in a second edition has obviously supplied a want, though it seems to offer no great advantage over similar works except that the subject-matter is discussed at some length in very simple language with the result that the field covered is very considerably less than would be expected from the number of pages.

In Britain it would be a useful textbook for medical students or for students in the higher classes in schools, but those who intend to specialise in chemistry require sterner stuff.

As a work of reference the book is totally inadequate, and for those who intend to continue with the study of organic chemistry it is not a satisfactory introduction. It cannot be described as a scholarly production, not that there are many serious mistakes but rather that many things could have been better expressed. The desire for simplicity has led the author into those half-truths which are the bugbear of University teachers; young students are apt to take statements in their first textbook very seriously and the disabusing of their minds is a difficult process.

O. L. B.

The Chemistry of the Monosaccharides and of the Polysaccharides. By HANS PRINGSHEIM. [Pp. 413.] (London: McGraw Hill Publishing Co., 1932. Price 24*s*. net.)

THIS volume is based on a series of lectures given by the author as George Fisher Baker lecturer at Cornell University.

The title is, perhaps, a little unfortunate as the chemistry of the monosaccharides occupies but fifty pages and is little more than an outline by way of introduction to the author's main subject, the chemistry of the polysaccharides. The di- and tri-saccharides occupy the next fifty pages and the bulk of the book deals with the more complex polysaccharides, cellulose, starch and their related compounds.

As one would expect from so great an authority as the author, the work presents a comprehensive review of a field in which great advances have been made during the last twenty years and nearly a thousand references to the literature indicate the thoroughness of the undertaking. It is sufficiently noteworthy to call for comment that justice is done to all workers, irrespective of nationality.

The subject-matter is confined to problems dealing with the elucidation of structure, and technical matters, such as the cellulose esters, are not touched upon except in so far as they contribute to the main thesis. Particularly interesting chapters deal with the bacterial degradation of cellulose and its role in the soil and the enzymatic degradation of cellulose and starch.

The whole constitutes a valuable contribution to chemical literature summarising our knowledge to the end of 1929, which all interested in the chemistry of the polysaccharides should possess.

O. L. B.

Microchemical Laboratory Manual. By FRIEDRICH EMICH with a section on Spot Analysis by FRITZ FEIGL. Translated by FRANK SCHNEIDER. [Pp. xvi + 180, with 88 figures.] (New York: John Wiley; London: Chapman & Hall, Ltd., 1932. Price 18*s*. 6*d*. net.)

THIS manual is a practical handbook for the use of students who wish to acquire the technique of qualitative and quantitative microchemical analysis as distinct from ultimate organic analysis.

Part I deals with the ingenious technique evolved largely by Prof. Emich, whilst Part II consists of 84 exercises such as a skilful student could easily carry out. These include the detection of the common inorganic anions and cations and of some common organic compounds together with a number

of quantitative separations and determinations of metals. The short section on the coarser method of spot analysis contains a description of the method and a number of examples.

The descriptions and instructions are very clearly given and no experienced chemical experimenter should have any difficulty in following them. Micro-methods are those of the future and it is to be regretted that few chemical students in Britain become acquainted with them. Apart from the advantage of an acquaintance with methods which may be of value in analytical operations, the student will learn to handle small quantities, an experience that will be of the greatest advantage; how few chemists can crystallise successfully the comparatively large quantity of 0·1 g of an organic compound. A number of the experiments in this book are well within the resources of a well equipped chemical laboratory and might, with advantage, replace a part, at least, of the qualitative analysis of complex mixtures on which so many students are now trained.

O. L. B.

Incunabula of Tannin Chemistry. By M. Nierenstein. [Pp. 167.] (London: Edward Arnold & Co., 1932. Price 12*s*. 6*d*. net.)

In spite of the author's explanation, the use of the term "incunabula" in the title is quite unjustified, this word has a very specialised meaning and cannot properly be applied to scientific papers published in Journals as late as 1803; would the author call a much erased solution of a crossword puzzle a palimpsest or a nitrifying organism nitrogen?

The book is a collection, in facsimile, of a number of early works dealing with tannin, from a passage in the Hortus Sanitatis (1485) with the first illustration of the oak-gall, to Davy's important "Account of some experiments and observations on the constituent parts of some astringent vegetables, and on their operation in tanning." What splendid titles the older chemists gave to their papers!

Porta (1669), as might be expected, deals with galls in connection with secret writing on eggs to circumvent the agents of the Inquisition. Tachenius (1677) describes a number of experiments showing that galls are blackened by solutions of iron and not of other metals. There follow a series of papers dealing with the attempted isolation of the astringent principle from oak galls by de Morveau, Piepenbring, Scheele, Richter and Davy covering the period 1778–1803 and then Bouillon-Lagrange's and Pfaff's papers clearly differentiating between tannin, gallic acid and pyrogallol. Biggin's paper, laying down the principles of the still accepted method of estimating tannin, is reproduced and finally, Davy's paper mentioned above. At the end Dr. Nierenstein adds a number of interesting notes and annotations.

Perhaps it is too much to hope that other bodies like the Committee of the Colston Research Fund, who have facilitated the production of this volume, will make possible the publication of similar works which can never have more than a very limited sale. Much of this work requires to be done so that the much-needed history of organic compounds before the nineteenth century can be written.

The book is attractively bound and the facsimile reproduction good except where the disgraceful English printing of the seventeenth century is encountered.

O. L. B.

British Chemicals and their Manufacturers. The official directory of the Association of British Chemical Manufacturers. [Pp. 429.] (London: The Association of British Chemical Manufacturers, 166 Piccadilly. Free to buyers of chemicals on application to the publishers.)

THIS directory is published in English, French, Spanish, Italian, Portuguese and German and consists of (1) a directory of members of the Association with addresses for correspondence and telegrams, telephone numbers and codes; (2) a similar list of affiliated Associations; (3) a classified list of products, each article being accompanied by the names of the makers who are members of the Association; (4) a list of proprietary and trade names; and (5) an alphabetical index.

The volume deals essentially with heavy chemicals and will be of the greatest value to all purchasers of chemicals at home and abroad, providing a guide to the range of chemical products manufactured by an Association of British firms with a total capital exceeding £200,000,000.

O. L. B.

A Comprehensive Treatise on Inorganic and Theoretical Chemistry. By J. W. MELLOR, D.Sc., F.R.S. Vol XII. U, Mn, Ma, Re, Fe (Part 1). [Pp. xiv + 944, illustrated.] (London: Longmans, Green & Co., 1932. Price £3 3*s* net.)

IT is a tribute to the patience and pertinacity of the author, and to the rapid progress of Inorganic Chemistry that almost the entire contents of Chapter lxv, upon Masurium and Rhenium, are due to investigations carried out during the last decade since the Treatise began publication, as most of the information now available regarding these two new elements was not in existence when vol. I was issued, and the admirable summary of what is known regarding them will be of special value to chemists, as there is probably no other similar source of information at present available.

Vol. XII contains only four chapters: lxiii (pp. 1–138) on Uranium; lxiv (pp. 139–464) on Manganese; lxv (pp. 465–81) on Masurium and Rhenium; and lxvi (pp. 482–919) on the physico chemical properties of Iron. As regards iron, Dr. Mellor has necessarily departed somewhat from his intention to exclude all information of a purely technical character, as the scientific and metallurgical aspects of this metal are so interwoven as to be inseparable, so that the 427-page chapter on the chemical and physical characteristics of the metal represents a really valuable summary of the physical metallurgy of iron and steel in all its forms.

At the beginning of the volume there is a short list of "errata" in its earlier volumes, the brevity of which is a tribute to the care taken in the writing and proof-reading of the whole treatise. The present volume fully maintains the standard of the previous volumes and, if it were possible, further enhances the reputation of its distinguished author.

F. A. MASON.

Outlines of Theoretical Chemistry. 5th Edition. By F. H. GETMAN and F. DANIELS. [Pp. ix + 643, and 180 diagrams.] (London: Chapman & Hall, Ltd., 1931. Price 22*s*. 3*d*. net.)

THE title does not clearly indicate the contents of this book, which by established custom in this country would be called a textbook of Physical Chemistry. That is not to say that anyone looking to it for an account of "Chemical Theory" would be disappointed—probably on the contrary. To the reviewer the book seems excellent, on the whole. It attempts too much, perhaps, for a book intended to be intelligible without reference to other books. It is difficult to say what standard is aimed at, but it should be very useful indeed to many university students who are making Chemistry their main subject.

The connection between the present book and the older one of the same name by Professor Getman alone is explained by Dr. Farrington Daniels:—"To introduce recent advances without offending old friends who cherish the foundations of a successful past; to keep pace with present tendencies toward the mathematical viewpoint without driving away students who are inadequately prepared; and to sift out the permanent from the trivial are the privileges and responsibilities of this revision. The first revisions of a book can be made by addition, but there comes a time, as in the present case, when for every addition there must be a corresponding subtraction. Approximately one-third of the book has been changed. The chapters on Elementary Thermodynamics, Kinetics, Photochemistry and Atomic Structure have been rewritten. The arrangement of chapters has been left unchanged except that two new chapters have been added, one on Chemical Thermodynamics using the notation of G. N. Lewis, and one on an Introduction to Quantum Theory."

The chapters on electrical conductance, electrolytic equilibria and hydrolysis, electromotive forces, electrolysis and polarisation, dilute solutions and osmotic pressure are admirable introductions. By comparison the chapter on the elementary principles of thermodynamics is disappointing; in particular, the explanation of free energy and its relationship to equilibrium on pp. 131, 132 is not adequate, especially since entropy is first introduced in the later chapter on chemical thermodynamics, where on p. 522 it says: "It has been shown (p. 132) that the tendency of a system to undergo spontaneous change may be measured by the decrease in free energy. . . ." There is logically an unavoidable difficulty in showing that a free energy criterion of equilibrium exists, without reference to entropy. Again, absolute temperature is taken for granted throughout the book, although far more elementary concepts are discussed.

On p. 111 the capacity factor corresponding to temperature as intensity factor is tabulated as heat capacity instead of entropy; on p. 115 the restriction "all other factors being kept constant" should be simply "at constant temperature." There is a minor inconsistency of notation, because on p. 109 it is said that Δx is to mean a *small* increment in x, but actually the symbol Δ is for the most part used as an operator indicating excess of x in the final state over the initial state in a change of any magnitude. An omission that one regrets in the chapter on Heterogeneous Equilibria is that no attempt is made to give a derivation of the phase rule or to explain even the nature of the proof. On p. 350, referring to catalysis by the walls of the decomposition of organic vapours: "In such cases the temperature coefficient is usually

small because the slowest process is the diffusion of the products away from the walls. . . ." This statement is out of touch with the real facts.

Two excellent features are the attention paid to modern physical-chemical apparatus, and the luxurious choice of examples for calculation. Many of the latter are of really first-rate pedagogic value. And special mention must be made of the very useful chapter (rather more advanced than the rest of the book) on Chemical Thermodynamics, in which the activity function is given prominence The notation of Lewis and Randall's textbook is used throughout for thermodynamic quantities, except that U is used in place of E for internal energy.

The price is high for a textbook which should have a wide circulation, but so much is compressed into its 620 pages, and the greater part of it is so clearly written that it is worth the money ; and clear print, good paper and a strong binding are an added compensation.

B. T.

Atomic Reactions. By MICHAEL POLANYI. [Pp. 63 + 22 diagrams.] (London: Williams & Norgate, Ltd., 1931 Price 6*s*. net.)

THIS small book contains (though it does not say so) the material of three lectures given in London in the Autumn of 1931, entitled "Recent Developments in the Theory of Chemical Reactions," "On Atomic Reactions without appreciable Inertia" and "On Atomic Reactions possessing Energy of Activation." The problem of chemical reactivity is here approached from the modern theory of valency itself as a starting-point, instead of along the more formal lines of the ordinary theory of reaction velocity. The first section gives a rather brief summary of the way in which Heitler and London's theory of chemical binding lends itself to an interpretation of the meaning of the energy of activation and to a prediction of its order of magnitude in especially simple cases. The reaction $H + H_2^{para} \rightarrow H_2^{ortho} + H$ is discussed in detail from this point of view, and the natural extension to saturated molecules is indicated.

The second section describes the experimental technique employed in the "method of dilute flames," which has been used so successfully for the study of atomic reaction by the author and others. The third describes briefly the necessary modification in this method when atomic reactions which are affected by a definite chemical inertia are to be measured, such as Sodium + Alkyl Halide = Sodium Halide + Alkyl Radical. The reaction velocities obtained provide a quantitative measure of the gradation in chemical reactivity as the alkyl radical is altered, and on passing from one halogen to another. The book closes with a most interesting speculation concerning the mechanism of a type of organic chemical reaction involving negative ions reacting with neutral molecules, and the difference between this and the case of hydrogen ions reacting with a neutral molecule.

Short as this book is, it is the only account in English of Polanyi's work which goes into any detail at all. It is too condensed in parts to be easy reading, but it provides a fascinating study for anyone interested in the fundamental realities of Chemistry. The only criticism of the book one would wish to make is that there should be much more of it. It is a pity, especially in view of the price, that the publishers have provided it with a paper cover only; it deserves and needs a more durable binding.

B. T.

Liesegang Rings and other Periodic Structures. By ERNEST S. HEDGES, D.Sc. [Pp. 122.] (London: Chapman & Hall, Ltd., 1932. Price 10*s*. 6*d*. net).

DR. HEDGES has succeeded in collecting the very sparse and scattered literature of the subject of physico-chemical periodicity and the structures which result therefrom into a concise volume which is arranged in logical sequence. The early part of the book is devoted to a review of the relevant properties of colloid media to the discussion at issue and is notable for its exceedingly simple and clear exposition of the subject. The data are summarised into the minimum of space, and possibly in some cases this is rather pushed too far. To turn to the Liesegang phenomenon itself Dr. Hedges outlines the form of the phenomenon and enumerates its many varied occurrences including the interaction of gases. Finally, he is careful to distinguish between periodic structures and periodic reactions. Chapter III is devoted to theories of the phenomenon and it is here that one would wish for a fuller discussion. Nevertheless, the summaries of the various aspects of different workers on the subject are clearly and fairly stated. It is obvious that the author's own work gives an authority to his views on this subject and that the prescription of a set of critical conditions (which may be concentrations or otherwise), is an essential for the true elucidation of the phenomenon. Outside these critical ranges of conditions the reaction can proceed without the formation of periodic structures. The author extends his study to periodic diffusion structures formed without chemical reaction, periodic crystallisation, and finally reviews the uncertain sphere of natural periodic structures. In this regard it is probable that the work should attract wide attention from biologists, zoologists and the like, for it is obvious that our knowledge of the physico-chemical formation of these structures, if such are the outcome of physico-chemical causes, is practically unknown. Thus in the case of crimp and waviness in wool, the exact reactions occurring within the follicle have not yet been elucidated, introducing work of co-operation between the histologist, the physicist and the chemist. The question of dehydration in this regard has also to be considered. Finally, the author has done a great service to science by recording such a complete bibliography of the subject at the end of the book. This alone is a great achievement and will be of untold value for future work on the subject. The book is carefully indexed and the illustrations are excellent. The author is to be congratulated upon the production of a concise and authoritative work upon a subject which as yet is in its initial stages of development.

S. G. BARKER.

GEOLOGY

A Textbook of Mineralogy, with an Extended Treatise on Crystallography and Physical Mineralogy. By E. S. DANA. Fourth Edition, Revised and Enlarged. By W. E. FORD. [Pp. xi + 832, with 1,089 figures.] (New York: John Wiley & Sons, Inc.; London: Chapman & Hall, Ltd., 1932. Price 34*s*. net.)

ONLY ten years have elapsed since the third edition of this great textbook, which has again been revised and enlarged by Prof. W. E. Ford. Considerable changes have been made. Seventeen pages have been added to Part I, Crystallography, dealing with crystal-structure and its X-ray investigation.

Part IV, on the origin, modes of occurrence, and association of minerals, is new to this edition. Part V, on descriptive mineralogy, deals with over 3,000 species, of which 220 have been added since the last edition. This material has been revised on information available up to January 1, 1932, and the paragraphs on occurrence have been largely rewritten. Another valuable feature of the descriptive part is that X-ray data have been incorporated wherever they were available. An almost incredible amount of data has thus been assembled in compact and handy form, and has been rendered easily accessible by good indexes of mineral names and of subject-matter.

This book is now by far the most complete, comprehensive, and authoritative textbook of mineralogy in the English language, and challenges comparison with German works such as Niggli's *Lehrbuch* which, however, does not provide descriptions of specific minerals as this does, and concentrates more on paragenesis. The new Part IV, dealing with the origin, modes of occurrence, and paragenesis of minerals, only occupies seventeen pages, and is thus not well balanced with the other parts. It is certainly the weakest section of the book; but this subject deserves a whole volume to itself.

Parts II and III, on Physical and Chemical Mineralogy respectively, have been revised but have had only minor additions. In the former the explanation of the Becke bright line effect is inadequate, and should have been supplemented by the more general explanation given by Anderson and Grabham. The author has also missed the very full reference report by Dr. A. Scott on colloid chemistry in relation to minerals, but on the whole the references are thoroughly up-to-date. There are appendices on the drawing of crystal figures, and of tables useful in the determination of minerals. No working mineralogist can afford to be without this very comprehensive instrument of research.

G. W. T.

A Key to Mineral Groups, Species, and Varieties. By E. S. Simpson, D Sc [Pp viii + 84] (London: Chapman & Hall, Ltd., 1932. Price 10*s.* 6*d.* net.)

In this book, Dr. E. S. Simpson, mineralogist and analyst to the Government of Western Australia, has compiled a dictionary of mineral names in order to consolidate and present the data regarding chemical composition, crystallographical system, specific gravity, refractive index, and source of information, in a compact and easily available form. The data are embodied in the standard compendiums such as Dana, Hintze, Doelter, Larsen, Winchell, Lacroix, and in mineralogical periodicals, but all these sources of information are incomplete in some particular. It is consequently often an exacting task to discover data relating to a given mineral even if a good library is available. Hence Dr. Simpson's key, which brings all the relevant data together in an alphabetical order, will undoubtedly prove as valuable to brother mineralogists as he says it has been to himself. A drastic pruning of synonyms, redundant names, and names of unimportant varieties has been purposely undertaken; even so, we estimate that Dr. Simpson has listed nearly 2,000 species as against the 3,100 listed in the new edition of Dana's textbook reviewed above. We have used Dr. Simpson's book and find that it answers its purpose excellently.

G. W. T.

BOTANY

Plant Sociology. By J. BRAUN-BLANQUET. Translated, revised and edited by G. D. FULLER and H. S. CONARD. [Pp. xviii + 439, and 180 text figures.] (London: McGraw Hill Publishing Co., 1932. Price 27*s.* net.)

PROFESSORS FULLER and CONARD are greatly to be thanked for their enterprise and industry in having translated into English Braun-Blanquet's textbook, *Pflanzensoziologie*; one may prophesy with confidence that the McGraw Hill Co. will not lose by having published it. It has been pointed out in the preface that the translation has been accompanied by some extension both by the original author and by the translators. One of the most satisfactory changes has been the collection of all the references into one very extensive and valuable bibliography at the end of the book: in the German edition there were several scattered and unco-ordinated groups of references making the whole very difficult to use. This is a matter of considerable importance since M. Braun-Blanquet makes such extensive reference to continental work that there is certainly no other textbook in existence which yields so full or so interesting a picture of the post-war development of ecological studies in Europe. The corresponding neglect of British and American work has been necessarily striking although the process of revision has added a few topics, and a few American or British illustrations of themes previously discussed. Especially welcome in the latter category are the soil map of the United States and the companion map showing the rainfall-saturation-deficit ratio; it is a pity that one should have to turn to another textbook altogether in order to see a map of the natural vegetation zones which presumably are the ecological phenomenon which has evoked the printing of these maps in the first place.

The book is composed of six parts differing much in size from one another:

I. The basis of social life among plants, 13 pages.
II. The organisation of plant communities, 55 pages.
III. Synecology or community economics, 223 pages.
IV. Syngenetics, 33 pages.
V. Synchorology, 14 pages.
VI. Systematics of phytosociology, 11 pages.

The reviewer does not agree with the title of the third part, which is simply an account of habitat factors, climatic, edaphic and biotic; in his view it is better to keep to the present usage in this country and restrict the term "synecology" to the study of the plant community in contrast with "autecology," the study of the intimate biology of the individual species within the communities.

The part devoted to the structure and organisation of plant communities (Part II) is largely an exposition of the Montpellier system of analysis and recording: the method is here given as if it were fully accepted by all working ecologists, and as if the principles of the statistics of distribution of plants in nature had in fact been worked out. It is to be hoped that the attention which the publication of this volume will inevitably call to these problems will result in thorough and competent analysis, and that the concept of "minimal area" will be critically examined. The analytical systems now applied separately to the estimation of "constancy," "frequency" or "presence" within each example of a community, and to estimation of

"constancy" between different examples of the community, should be co-ordinated into one statistically satisfactory schema. Until this has been achieved no real progress is possible in the analysis of plant communities along statistical lines, and we should be grateful that this book will show the emphasis rightly placed by continental workers on this approach to phytosociology

The part of the book covering the phenomena of succession (Part IV, Syngenetics) is only 33 pages, and this, supplemented here and there in the section on habitat factors, about represents the emphasis laid upon those principles of vegetational development which have been such a fertile basis for British and American ecological investigations through the past fifteen or twenty years Some idea of the extent to which Braun-Blanquet disregards these principles can be gauged from the absence of even the terms "hydrosere" and "xerosere" from the book; after that we are prepared to find no mention of the most useful concept used by Tansley, of autogenic and allogenic succession.

Such vexed questions as these will only be solved by the stimulation of wider and deeper investigation, and no book could be more stimulating to the student ecologist than this. It raises a million queries and suggestions and though one would prefer everywhere more critical, and slightly less dogmatic treatment, it may be that in rousing vigorous interest the book is fulfilling the most important function possible. It certainly should be found in the student libraries of all Botanical institutions in English-speaking countries.

The name of the publishers is sufficient index to the pleasing format and presentation of the volume.

H. G.

ZOOLOGY

Manual of Animal Biology. By G. A. Baitsell. [Pp. xi + 382, with 12 full-page figures] (New York: The Macmillan Company, 1932. Price 12*s.* 6*d.*)

This elementary textbook, by the Professor of Biology at Yale, gives a simple account of the structure and physiology of a number of animal types used in laboratory teaching. They are Amœba, Euglena, Volvox, Paramecium, Vorticella, Grantia, Hydra, Obelia, starfish, earthworm, crayfish, grasshopper, honey-bee, clam (Venus), and frog. There is an introductory chapter on elementary physiology and a final chapter on vertebrate development, while a general account of vertebrates is given in the frog chapter. Instructions for laboratory work on each type are printed at the end of the book on single perforated sheets. The book is intended to be used in connection with Woodruff's *Animal Biology*, to which there are numerous references.

The special feature of the book is the excellent series of full-page drawings, mostly original and mostly by Richard E. Harrison. They are a welcome improvement on the usual textbook illustrations, and have the additional merit of showing the animals in many cases in their natural surroundings.

E. S. R.

Fundamentals of Biology. By J. W. Stork, M.A., Biology Master, Charterhouse, Godalming, and L. P. W. Renouf, B.A., Dip. Agric., Professor of Zoology, University College, Cork. Director of the Cork University Biological Station, Lough Ine, Co. Cork. [Pp. xv + 448, with 180 illustrations.] (London: John Murray, 1932. Price 6*s*. net.)

This book is not written with any particular examination in view and covers adequately, as to the types and subject dealt with, the Biology syllabuses of a number of Elementary Examinations. The arrangement of the subject-matter is good and the types are dealt with in sufficient detail for the purpose, while the number of illustrations and the subjects for illustration have been well thought out. The actual carrying out of some of these, however, seems to call for a certain amount of adverse criticism, *e.g.* Fig. 75c on p. 180 is supposed to show endogenous origin of a lateral root but shows exogenous origin of some structure from an organ which is not a root, similarly Fig. 11 is not a good drawing of a stomate, nor is Fig. 102, and the walls of some of the cells in the latter drawing and in other figures are so drawn, being incomplete, as to give a reader a wrong conception of their structure and method of formation; in Fig. 160, the floral diagram of the buttercup does not show the quincuncial arrangement of the petals, the spiral arrangement of the stamens nor the apocarpous nature of the carpels; Fig. 172 does not show the characteristic infolding of the mesophyll cells of the Pinus leaf and the epidermal cells are given lumina that are much too large. While it is true that the moss and liverwort sporogonia are referred to as sporangia and that it is suggested that the normal method of pollination of the willow is by wind, the text seems, on the whole, to be free from error. Useful appendices are supplied, a good index and derivations of terms are provided on their first appearance in the text, while the price is a very reasonable one.

E. M. C.

Biology. An introduction to the Study of Life. By H. Munro Fox, Professor in the University of Birmingham and formerly Fellow of Gonville and Caius Colleges, Cambridge. [Pp. xiv + 343, with 152 illustrations.] (Cambridge: At the University Press, 1932. Price 6*s*. net.)

This addition to the growing number of books on Biology should prove a very welcome one. The clear paragraphing makes reading easy and is certainly a feature to make its appeal to the younger reader. The illustrations are well selected and well executed and the inclusion of classical illustrations such as that of the flea and part of a bird's feather from Robert Hookes' *Micrographia* and the mistletoe by Malpighi and modern ones such as that showing stages in the division of an Amœba by Bělař or the movement of a cilium by Gray, is much to be commended.

An appendix is provided with Greek and Latin derivations of words. The general treatment of the book is elementary and it should prove a good groundwork to all who require an introduction to the subject and be a stimulus to further study.

E. M. C.

Chromosomes and Plant-breeding. By C. D. Darlington, Ph.D., D.Sc. Cytologist, John Innes Horticultural Institution, with a foreword by Sir Daniel Hall, K.C.B., F.R.S., Director of the John Innes Horticultural Institution. [Pp. xiii + 112, with 24 illustrations.] (London: Macmillan & Co., 1932. Price 7*s.* 6*d.* net.)

Based on a series of articles in the *Gardeners' Chronicle*, this book gives a general introduction to the study of plant chromosomes with reference to plant-breeding. The earlier chapters deal with the cell and its nucleus, mitotic and meiotic divisions in a very clear manner, but reduced to the very simplest outline This portion of the book can only serve, as was possibly the intention of the author, to remind the reader of facts already known. The main portion, however, considers the question of polyploids of various kinds, especially tetraploids and triploids, their origin and hereditary behaviour, and seeks to connect these with their cytological structure and behaviour. Trisomics and haploids are also treated in a less detailed manner. The illustrative examples are not limited to plants of economic importance and the work of the John Innes Horticultural Institution furnishes many interesting examples. Explanations are put forward for ring-formation, shift, etc., and of some kinds of infertility. The book is a clearly written introduction to an intricate subject. E. M. C.

The Essentials of Biology. By James Johnstone, D.Sc., Professor of Oceanography in the University of Liverpool. [Pp xvi + 328, with 44 diagrams.] (London: Edward Arnold & Co., 1932. Price 16*s.* net.)

This book reviews the theoretical aspects of zoology and consequently is different in factual content and mode of treatment from the more common kind of book based more or less on the description of a series of types with notes on theoretical considerations appended to them. It forms a useful companion reading book to accompany these and to round them out and provides an interesting and provocative commentary upon them. Certain statements will not pass without criticism, *e.g.* the tube feet of strafish adhere to the substrata during locomotion (p. 72) this does not appear to be the case; "it is probable that molluscs, etc., may also absorb dissolved organic matter contained in the water currents that flow through their mantle cavities" (p. 79), this is a statement made when the absorption of food was considered to be a simple osmotic phenomenon; in the lower reptiles the "pineal gland" is a median eye whereas in Sphenodon it is obviously a paired structure; it is an incomplete definition of mendelism that is given on p. 237, etc. Auricle (p. 287) is not a good term for atrium. Castles (p. 34) is an obvious misprint for astes. Apart from these minor blemishes the book can be read with enjoyment and profit by all students of zoology. It is usefully indexed and illustrated.

Since the publication of this book its distinguished author has died and British zoology has lost a clear-minded and original thinker.

C. H. O'D.

The Centenary History of the Entomological Society of London. By S. A. Neave, O.B.E., D.Sc., assisted by F. J. Griffin, A.L.A. [Pp. xlvi + 224, illustrated.] (London: Published by the Society, 1933. Price 10*s.* 6*d.*)

The Entomological Society of London came into existence in 1833, received its Charter of Incorporation in 1885 and, on the occasion of its centenary, it has

become "The Royal Entomological Society of London." In view of its approaching centenary, the Council decided that a history of the Society should be written and it fell to the Honorary Secretary to carry out the wishes of the Council. Whether, in any case, a Secretary is entitled to the not unmixed honour is perhaps open to question but, in this case, the volume itself is abundant evidence that the right man was chosen for the work. That the task has been laborious is obvious and Dr. Neave mentions in the Preface the valuable assistance he has received from the Registrar, Mr. F. J. Griffin.

The first 62 pages are divided into seven chapters or periods in the history of the Society, but the first chapter, covering 88 years and entitled "Origin and Foundation of the Society, 1745–1833," deals with various abortive attempts to get a Society started and it is interesting to note that, in so far as they are known to exist, all the original records and minute books of these ephemeral societies are in the possession of the existing Society.

The chapters describe the good and bad periods and how, when financial disaster threatened, one or more Fellows always came forward and saved the situation. There were also quarrels as to policy, and personal feelings were more than once in evidence and the accounts of those stormy times are given with admirable tact and discretion and undoubtedly add interest to the book.

The eighth chapter deals with the Collections of the Society and of their ultimate disposal in 1863. From the fact that one of the first steps taken by the Society after its inauguration was to start a collection, it is obvious that the latter was regarded as one of its most important assets. If funds and accommodation had permitted, the Society might now possess many valuable specimens including numerous types, and those who hold that all types should be in the National Museum will therefore doubtless be thankful that things turned out as they did.

The ninth chapter deals with the development of the Library and one important point brought out is that it was apparently the possession of too many books which saved the Society from being absorbed by the Linnean Society in 1874.

In the tenth chapter, dealing with the publications, it is mentioned that in 1867 the Society commenced to publish a Catalogue of British Insects, but only four parts were published and it appears that the scheme then broke down upon a question of nomenclature. At the present time an attempt is being made by the Association of British Zoologists to produce lists of the British fauna and as, at the same time, both that Association and the Entomological Society are considering the whole question of nomenclature, it is to be hoped that these very useful lists will at length be published.

A short but clear statement of the Society's Finances, written by the Hon. Treasurer, Mr. A. F. Hemming, completes the historical part of the book unless we include the delightful introduction by the President, Prof. E. B. Poulton, where he gives us reminiscences from the year 1883, in which he became a Fellow of the Society.

The second half of the book contains, among other things, short biographies of some of the distinguished men who have been Fellows of the Society and also a complete list of Fellows with the year of their election and of the death of those who have passed on. I may say that I am not greatly interested in histories, but the style in which Dr. Neave tells his story is so attractive that, before I had been asked to review it, I had read all there was to read with very great enjoyment.

FRANK BALFOUR-BROWNE.

MEDICINE

The Wisdom of the Body. By WALTER B. CANNON, M.D., Sc.D., LL.D. [Pp. xv + 312, with 41 illustrations.] (London: Kegan Paul, Trench, Trübner & Co., 1932. Price 12*s*. 6*d*. net.)

THIS is one of the best books on physiology which has appeared for a long while. It is synthetic and biological rather than analytical and mechanistic, and describes as far as may be how the body works as a whole. A live organism is an extremely unstable system, and in virtue of that very instability it manages to maintain itself in a singularly constant state. Prof. Cannon describes how it is done and how the activities of the whole organism come to be so much more than the sum of the activities of its parts. The blood maintains a "normal" composition, the body has a "normal" reaction and a "normal" temperature: the constancy of these constants through all the changes and chances of external environment and internal function is sufficient evidence of the existence of regulating arrangements in the body of a delicacy and capacity that physiologists are only now coming to realise. A man can live in the Arctic or the Tropics, he can lie in bed and use 250 c.c. of oxygen a minute or run hard and use 10 litres, he can drink acid or alkali and get on quite well all the time: the body indeed behaves continually as if it were wise. We can hardly doubt that this wisdom is the product of evolution. The blood of marine invertebrates, for example, varies in composition with the water in which they live: teleostean fishes have learned to segregate their blood from the environment, and no doubt their tissues do their work better in the privacy thus secured. It seems sometimes that the differentiation and specialisation of structure and function which increases progressively through the animal series must introduce dangers, and that it might be better if for instance the mammalian body were not so very particular about the reaction of the blood. This would surely be so if the body had not developed these regulating mechanisms in parallel with the refinements of activity which need constant conditions. And since natural selection acts through exceptional circumstances rather than the small ups and downs of ordinary life, the regulations must have a wide margin of safety—which in fact they have.

A. E. BOYCOTT.

PHILOSOPHY AND HISTORY OF SCIENCE

The Universe of Science. By H. LEVY, Professor of Mathematics at the Imperial College of Science, University of London. [Pp. xiii + 224.] (London: Watts & Co., 1932. Price 7*s*. 6*d*. net.)

THERE was a time, not so long ago, when the exposition of the aims, methods, principles and broad results of science was left to logicians and philosophers. Recently, however, scientists have taken over this function. It is all to the good that men of science should speak for themselves, even if it cannot be pretended that they are doing it better than the logicians have hitherto done it for them, or even as well. Prof. Levy, for instance, gives eight different views of the aims of science held by as many scientists, and he disagrees with seven of them. Onlookers sometimes see more of the game than do the players themselves. So the philosophical logician is likely long to retain a useful place in the exposition and criticism of the methods and principles of science. But he will feel grateful for such accounts as Prof. Levy's, for they

contain helpful self-revelations, even if they are not always expressed in the most suitable or customary terms. If one may do so with all deference, I would ask scientists who write on these topics to familiarise themselves with the existing logical and philosophical terminology, instead of using, and sometimes abusing, other substitutes. What gain is there, *e.g.* in substituting "isolation" and "unpicking," etc. for "abstraction" or "analysis," when the latter have the advantage of not always suggesting a real breaking up? What good is there in the paradoxical use of "prediction" (p. 144) for the inferential reconstruction of the past from present data? And is it not quite misleading to use "uniformity" instead of "unity" (p. 20), or to restrict "quality" to what is measurable (p. 104), as if heat were not a quality before the invention of the thermoscope and the thermometer? However, these are comparatively minor matters. Prof. Levy's book as a whole is so racy and readable, in spite of the big problems discussed, that it may be warmly recommended to all who are interested in the aims and methods of science.

In some ways the most interesting part of the book is the discussion of the place of mathematics in science and the criticism of the idealistic tendency commonly found among mathematicians. From Plato to Eddington and Jeans mathematicians have shown and still show a peculiar weakness for ontological idealism. And, as mathematicians are at present the most vocal of scientists, the general reader is apt to get the impression that idealism is the only, or at least the most, scientific philosophy. Prof. Levy has no difficulty in accounting for this tendency and in showing up its inconclusiveness. All this, it is true, has been done before; what gives peculiar weight to Prof. Levy's criticism is the fact that he is himself an eminent mathematician, and consequently not to be gainsaid as lightly as those who are not, and do not profess to be, mathematicians.

Less important is the long discussion about determinism versus free-will. Professor Levy is indeed right in his criticism of Eddington's cheap defence of orthodoxy. But, like Eddington and many others, he fails to see that "determinism versus free-will" is a false antithesis. Free-will is itself a form of determinism, namely, self-determination. Its antithesis is external determinism or compulsion. For reasons which Prof. Levy has made perfectly clear in his account of the "method of isolation" (or abstraction), and which Spinoza had explained several centuries before him, no finite being is absolutely free; but there are degrees of freedom and of compulsion—the greater the external compulsion, the greater the bondage, while the more self-determination, the more free-will. Action not at all determined by a man's character and history would not be *his* action at all, but something that just happened to him.

The only misprint I have noticed is that on p. 114 where "$32t^2$" should be "$16t^2$."

A. WOLF.

The Mediæval Sciences in the Works of John Gower. By GEORGE G. FOX, Assistant Professor of English, North-Western University. [Pp. 164.] (Princeton: Princeton University Press, 1931. Price 18*s*.)

THIS book is one of the signs of the times. There is a growing appreciation, among scholars, of the importance of a knowledge of the scientific atmosphere in which the great masters of literature wrote. Prof. Fox, realising that this

holds good of Gower and Chaucer as well as of subsequent writers, accordingly undertook to trace and display the scientific allusions and implications contained in the works of John Gower. He has done this admirably in a series of chapters on Nature and Fortune, the Microcosm, the Macrocosm, Astrology, Dreams, Alchemy, Magic. To judge from the gleanings of Prof. Fox, Gower's knowledge of the science of his time was not nearly as extensive as was that which Chaucer had. Still it was not inconsiderable. And this book is a welcome companion to W. C. Curry's book on *Chaucer and the Mediæval Sciences* The author has relied mainly on Duhem's and Thorndike's standard works on the history of science. It was not his purpose to make a new contribution to the history of mediæval science; but he has certainly given us an interesting study of the influence of mediæval science on one of the greatest masters in the history of English literature

A. WOLF.

The Scientific Outlook. By BERTRAND RUSSELL. [Pp. 285] (London: George Allen & Unwin Ltd, 1932 Price 7s. 6d net.)

MR. RUSSELL mentions a learned theologian who had come to understand everything except why God created the world Mr. Russell himself apparently has not yet come anywhere near that problem, as he is not sure of the existence of the world, much less of God. But setting out with "animal faith" in the existence of a world of sorts, he directs his powers of scientific insight and philosophic imagination to play upon it so as to illuminate its present drift and its future possibilities. In the main it is, no doubt, a serious book, and contains ample food for serious thought. Yet some sort of impish spirit pervades it all, makes the reading of it as pleasant as that of light literature, and gives it an ending which is sufficiently surprising to be worthy even of the best fiction.

There are three main topics discussed in this book: (1) the nature and scope of scientific knowledge; (2) the increased power resulting from scientific technique; (3) the changes in social life likely to result from this increased power.

Scientific thought, according to Mr. Russell, is essentially power-thought, the power which a knowledge of causal laws gives. One hundred and fifty years of modern science have proved more explosive than 5,000 years of pre-scientific culture. Science has indeed another side which makes it akin to art and religion. But our age is one which increasingly substitutes power for the older ideals, the love of power having thrust aside all the other impulses that make the complete human life. And power may be abused, not only by individuals, but even by whole nations. Even in the realm of pure science, Mr. Russell remarks, English patriotism made English mathematics negligible for a hundred years through the rivalries between the partisans of Newton and those of Leibniz. So it is not surprising to find our author fancying a world-government in which nationalism will be treated as treason. But it is unnecessary to give the details of Mr. Russell's Utopia. He has more than sufficient humour to realise that whatever happens in the future is likely to be something which cannot be foreseen. Some of his warnings against present tendencies are, however, worthy of serious attention, and recent events have only added significance to them. Here is one of Mr. Russell's dicta: "The man drunk with power is destitute of wisdom, and so long as he rules the world, the world will be a place devoid of beauty and of joy."

Many readers, besides the present reviewer, may disagree with some of Mr. Russell's views on scientific method, theory of knowledge, etc. But every reader will find the book at once entertaining and stimulating.

A. WOLF.

Life of Mendel. By HUGO ILTIS. Translated by EDEN and CEDAR PAUL. [Pp. 336, with 10 illustrations and 12 plates.] (London: George Allen & Unwin, 1932. Price 12*s.* 6*d.* net)

DR. ILTIS, who is a native of Brünn, where Mendel spent the greater part of his life, has been at great pains to collect the scattered and scanty information about his hero. He has made a very good job of it, and has produced a thoroughly interesting book.

Mendel was the son of a small farmer or smallholder in Moravia, and in his matter-of-fact-ness and tenacity of purpose he showed the marks of his peasant origin. His early life was one long struggle with poverty and the difficulty of obtaining an adequate education. By the sacrifices of his family and his own doggedness he finally reached an institute of near University rank, and after finishing his course he became a novice at the Augustinian monastery at Altbrunn. Later ordained priest, he spent some years as a teacher in the High School at Znaim, and subsequently at a school in Brunn itself. It was in the gardens of the monastery in the 'fifties and 'sixties that he carried out his historic researches on the hybridisation of peas. In 1868 he was elected by his brethren Abbot of his monastery, at the comparatively early age of forty-six, and thereafter till his death in 1884 he was too busy with the cares of administration to give any further attention to research, though he retained his interest in gardening and bee-keeping. His last years were darkened by a dispute with the State, in which he seems to have shown more obstinacy than skill.

His famous and fundamental paper, published in the transactions of the local natural history society, received as we know no recognition at all; even the botanist Nägeli, with whom Mendel was in correspondence, failed to appreciate its importance, and his influence diverted Mendel to the somewhat unprofitable study of hybridisation in *Hieracium*. The paper came some thirty years too soon, and it was not till 1900 that the true significance of his work was realised by De Vries, Correns, and Tschermak, who rediscovered the Mendelian laws.

Dr. Iltis gives a full account of Mendel's work and its significance, in a form which is readily understandable. There are a number of excellent photogravures of Mendel. All pious Mendelians should possess this book.

E. S. RUSSELL.

A History of Fire and Flame. By OLIVER C. DE C. ELLIS. [Pp. xxiv + 440, with 22 plates.] (London: Simpkin Marshall, 1932. Price 15*s.* net.)

A SCIENTIFIC reviewer may well approach his task on this book in fear and trembling; for it is published under the auspices of the Poetry Lovers' Fellowship and the International Fellowship of Literature and, before he has opened it, the brilliant yellow jacket tells him that Professor Lascelles Abercrombie says it is "rich and vivid" and Mr. Walter de la Mare adds that "every page is aglint with imagination." It is dedicated to Dr. R. V.

Wheeler, that eminent pyro-chemical philosopher, as the author might describe him, and the sight of his more familiar name puts heart into the reader.

Dr. Ellis is at once poet and scientist and here he has written of Fire, mysterious and majestic in all its long story, of man's awe and worship of it, of its symbolism and its rôle in religion, in priestcraft and in witchcraft, of its multifarious forms, of the lore of the wood-fire and the hearth, and, finally, of its modern application for warmth, light and power and of the recent scientific studies of the propagation of flame. He gives some magnificent illustrations and a very useful bibliography. The index is a model of its kind; it extends to 49 pages with double columns, and there are about 50 entries in each column. And when the book is read, it is a pleasant occupation to turn the leaves of this generous index, choose here and there among its 5,000 items and read once more some of the many interesting sections which richly deserve the high praise of the author's literary sponsors.

Dr. Ellis is mistaken in supposing that there is no English version of Mayow's *Tractatus Quinque*: the Alembic Club published one in 1907. Further, the well-known laboratory apparatus was invented by Kipp, not by Kipps: Kipps is an invention himself

This is a book that every chemist should enjoy reading, since it will afford him much new information about those past times when scientific knowledge was in its infancy, especially in the case of chemistry, which was often enough less science than folklore. It is very well written in a pleasing narrative style; and the author is to be congratulated on the completion of the obviously heavy labours involved in the preparation of a book of this kind.

D. McKie.

Sir Bertram Windle: A Memoir. By Monica Taylor, D.Sc. [Pp. xii + 428, with frontispiece and 3 plates.] (London: Longmans Green & Co., 1932. Price 12*s*. 6*d*. net.)

In compiling the biography of the late Sir Bertram Windle, F.R.S., Dr. Monica Taylor has allowed her subject largely to tell his own story by quotations from his letters and other writings. Windle, born of distinguished ancestry, possessed most versatile gifts and was an outstanding worker in many fields. His boyhood was passed mostly in Ireland and he entered Repton only after his father had foiled his ambition to go to sea—an action that he never wholly forgave; for, a few years before his death, he wrote that he would exchange all his distinctions for an Admiral's stripes.

From Repton Windle proceeded to Trinity College, Dublin, taking his M.D. in 1883. In 1884 he was elected to the Chair of Anatomy at Queen's College, Birmingham. Here he became leader of the movement for establishing a University in Birmingham, and by his strenuous fight and years of struggle Windle may truly be said to have made that University. He was elected F.R.S. in 1899. In 1904 he was appointed President of Queen's College, Cork, and began his constructional labours over again in the long fight to secure a University charter for Cork. He was knighted in 1912, left for the University of Toronto in 1919, and died in Canada in 1929.

In his early days at Birmingham Windle joined the Catholic Church and throughout his long and active public life never wavered from his adopted faith, taking great place among his co-religionists and among Catholic apolo-

gists. He was, too, a leading propagandist in the cause of Irish Home Rule, and, in the troubled years that followed the rising of 1916, played a great part in Irish affairs until his departure for Canada. As an original investigator, Windle was specially interested in teratology and comparative myology, to which he made notable contributions: his archæological work was almost as widely known.

Dr. Taylor's book ably answers its purpose in giving a short but comprehensive account of the life of one of the most interesting personalities in the scientific world of the last fifty years. As the story is unfolded here, Windle appears as a man of great earnestness and honesty of purpose, possessed of a great fund of humour and a determined and tireless worker in the causes of science and education. He was in contact with many, if not most, of the great figures of his time in science and in politics, and the letters published here shed interesting light on many famous names: Windle's comments are often very shrewd, but never malicious, and convey much of his attractive personality.

D. McKie.

The History of the Phlogiston Theory. By J. H. White, Ph.D. [Pp. 192.] (London: Edward Arnold & Co., 1932. Price 6s. net.)

Dr. White relates here the history of the phlogiston theory from its foundation by Becher and its development by Stahl through its subsequent triumphs to its final overthrow by Lavoisier and his followers. The theory arose in answer to that ancient philosophical problem or group of problems, the nature of fire, flame, burning and combustibility, to which it provided the first generalised solution in agreement with known chemical facts. It appears, however, from Dr. White's work that Becher, in supposing that a principle, *terra pinguis* or "oily earth," was present in all combustible bodies and on combustion was expelled from them, led chemistry a step backwards by ignoring the work of those chemists who had begun to direct attention to the part played by air in combustion: and that Boyle, despite his studies on the effects of vacuum on combustion, helped this retrograde movement by his conclusion that the increase in weight of metals on calcination was due to the addition of "fire matter," since one phlogistonist after another, following Becher, invoked his explanation to account for this fact.

It appears, too, that the earlier exponents of the theory did not regard phlogiston as a substance but a principle, immaterial, imponderable. Some of them compared it with light. Juncker in 1730 was the first phlogistonist to consider phlogiston as a material substance and, accordingly, when faced with the problem of the gain in weight of metals on calcination, he offered the explanation that phlogiston levitated whereas other substances gravitated. This idea, however, contrary to what has generally been supposed hitherto, received no general acceptance, although the belief that phlogiston was a material substance increased in the second half of the eighteenth century. When this latter idea became more general, the theory was doomed and, as Dr. White shows, it became gradually involved in inextricable difficulties and was finally overthrown by Lavoisier. As for its last exponents, they remind the reader of Themistius's Aristotelians in *The Sceptical Chymist*, in that they were not "very solicitous to gather experiments to prove their doctrines, contenting themselves with a few only, to satisfy those that [were] not capable of a nobler conviction."

Dr. White is to be congratulated on this first serious historical study of the phlogiston theory, and his book, it is hoped, will correct the inaccuracies, misconceptions and misstatements that are nowadays current with regard to it, notably the statement repeatedly met with that the phlogistonists supposed that phlogiston levitated. As for the term itself, it was Stahl and not Becher that brought it into general use and defined it precisely.

1793 on p. 121 should read 1791.

D. McKie.

The Story of Science. By David Dietz. [Pp. xvii + 387, with frontispiece and 34 plates and 12 other illustrations.] (London: George Allen & Unwin, 1932. Price 10*s.* 6*d.* net.)

Written to give the general reader a picture of present-day science taken as a whole, this book is not so much a history of science, as might have been supposed from its title, as a very rapid survey of the historical growth of science followed by a much more extensive account of its modern developments. The first section deals with the universe, its size, its parts and its structure, and the second with the earth, its geological history and its fossil records

The third section, "The Story of the Atom," opens with a short account of the rise of chemistry which contains a number of serious errors. The Arabians did not, as the author says, add three elements, namely, sulphur, mercury and salt, to Aristotle's four, but rather developed a theory that the metals were formed by the union in various proportions of the two principles, sulphur and mercury. The quotation from Paracelsus on p. 183 refers, not to the alchemists, but to the chemical physicians. Boyle's classic is named as *The Skeptical Chymist*,—"that was the spelling he used," (p. 184),—but the cautious Boyle was not a reformer, least of all in spelling, and he wrote *The Sceptical Chymist* and spelt it as any other English writer of his own time or even of a century later would have done. Further, the phlogiston theory originated with Becher, not with Stahl. As for the statement that "the progress of chemistry was also delayed by the idea that heat was a substance" (p. 185), the foundations of modern chemistry were solidly laid by Lavoisier more than 60 years before science abandoned the caloric theory. And Dalton did not induce his Atomic Theory from experimental facts, but deduced it from theoretical considerations, as was shown by Roscoe and Harden in 1896 after an examination of his note-books. As for the description of a certain famous physicist as having been "a tall young man with auburn hair and sympathetic eyes"—what is this doing here?

The fourth section deals with the rise of biology, the nature of life, evolution, and, finally, the unity of the universe. Apart from the errors mentioned, the book provides a well-written account of the present scientific outlook and the illustrations are well chosen.

D. McKie.

Comenius in England. . . . As described in contemporary documents, selected, translated and edited with an Introduction and Tables of Dates, by Robert Fitzgibbon Young. [Pp. vii + 99, with 12 illustrations.] (London: Oxford University Press, 1932. Price 10*s.* net.)

This further contribution by Mr. Young on the great educational reformer of the seventeenth century is very welcome, giving, as it does, much informa-

tion of permanent historic value relating to English culture of the period just prior to the great rebellion.

Comenius's visit to England is described and its significance illustrated by translations of his own account and of various contemporary documents. The work is copiously annotated and indexed, and has numerous illustrations, including a reproduction of the fine Amsterdam portrait of Comenius. There are two interesting and useful Tables, one of Dates relating to the life of Comenius and another to illustrate the development of ideals of social improvement and the organization of scientific progress by Academies and associations from 1470 down to the latter part of the eighteenth century.

Comenius came to England at the desire of the English Parliament, but the troubled times led to his plans and those of Samuel Hartlib, who was responsible for his visit, being abandoned. Mr. Young's research has given us a clearer idea of the opinions held by the thinkers of that day regarding the higher teaching as advocated by Comenius. His plans received the approbation of all scholars to whom they were made known. His "pansophic" idea spread quickly through many lands. Whether the impression it made in England was sufficient to have any actual relation to the foundation of the Royal Society is perhaps difficult to decide, but certain it is that such an institution was visualized by Comenius and, when founded, the Society duly received his commendation.

One hesitates to point to faults or mistakes in a book so ably introduced, edited and commented, as occasional mis-statement of facts is inevitable. In translations, language and style must always be a matter of taste and opinion. Mr. Young renders D. (Dominus) by Master, when we would have preferred mere suppression. Master Ussher, Master Selden, Master Descartes ring somewhat harshly on the ear. John Winthrop, who died in 1676, surely never corresponded with Sir Isaac Newton. And the date of the Boston printing of his Correspondence (p. 93) should be 1878, not 1896. The title of the *Philosophical Transactions* is steadily misquoted: the name of *The Royal Society* did not appear on the title-page until 1776.

H. W. R.

MISCELLANEOUS

Northern Lights. The Official Account of the British Arctic Air-Route Expedition. By F. SPENCER CHAPMAN. [Pp. xv + 304, illustrations and maps.] (London: Chatto & Windus, 1932. Price 18*s*. net.)

THIS volume sets forth the plans and the achievements of this expedition. Watkins, in the introduction, indicates the work which was planned whilst the modifications are detailed in the subsequent chapters which cover the achievements.

From the finding of a base to the return passage we have a full, detailed and very interesting account of the work done.

The whole life story of the party is vividly portrayed. All they did and encountered is told with charm. It is from the quiet manner of the book that it is possible to get in touch with the atmosphere of the life which the small band of men lived.

A story as fine as this has no need of rhetorical aids. Plain facts such as this suffice: "For three days it rained in torrents, water streamed through our tents and under our beds in little streams. Although this decreased our comfort, it saved us going outside for water" (p. 237). It is impossible

to allude adequately to the 15 chapters which cover the main report of these proceedings, which include journeys by land, sea and air, and deal with routine tasks, the life of the Eskimo, and a wealth of local detail. In addition to this, one grasps the thrills and escapes of the party, and the wonderful comradeship which contributes so largely to the success of their work, and of their contacts with the Eskimos. The scientific work is further summarised in a series of appendices.

So admirable is this book, which gains further from the hundred photographs, that it may appear harsh to make criticism. This account is the "official" account, so one may be pardoned for regretting that the detail of Chapter 13, Ivigtut Journey (by J. M. Scott), is not equalled in the other chapters, and there is no index.

The expedition has been described as "the most important Arctic Expedition for fifty years." "It is a tale of prowess," and a book which will stir many and interest all.

The small band of men feel they are held together by something which could be shared by no one else in the world. Though this is obviously true, they may feel assured that many others feel drawn near them through this book and regret, with them, the gaps which have already been made in their circle.

J. Eling Colleclough.

The Official Year Book of the Scientific and Learned Societies of Great Britain and Ireland. 49th Annual Issue. [Pp. viii + 167.] (London: Charles Griffin, Nov. 1932. Price 10s. net.)

We are glad to learn from the preface to the new edition of this useful reference book that the concise arrangement introduced in the previous issue has been cordially welcomed. The varied nature of the material to be classified must render the compilation far from easy, but the difficulties have been admirably overcome; the index—on which the usefulness of such a book largely depends—has passed every test we have applied. The only omission from the book noticed is that of the Society of Experimental Biologists.

P. J. E.

The Psychology of Animals in Relation to Human Psychology. By F. Alverdes. [Pp. viii + 156.] (London: Kegan Paul, Trench, Trübner & Co., 1932. Price 9s. net.)

This new volume in the International Library of Psychology and Philosophy, translated from the German of the Professor of Zoology in Marburg, may be thoroughly recommended as a clear and simple introduction to the study of animal behaviour from the psychological point of view.

There have been few more interesting or more significant developments in recent years than the rapid growth of a new science of behaviour, freed from the trammels of physiology which have so greatly hampered it in the past. Prof. Alverdes has taken part in this new movement and is well qualified to expound it. It is characteristic of this modern psychology of animals that it regards behaviour as a unitary activity, which is not a mere summation of physiological processes; it rejects as inadequate the physiological theories of tropisms and reflexes. It recognises that each animal lives in a perceptual

world of its own, and that this perceptual field is not a pure summation of sensory stimuli, but an organised whole or pattern (Gestalt).

Prof. Alverdes' criticism of the tropism theory is particularly good, and his account of Gestalt theory and of instinct is both simple and adequate. The work is in no sense a textbook, nor a compendium of facts; it must be regarded rather as an elementary introduction on method, and as such it is extremely valuable. The short bibliography covers a number of the more important papers and books of recent date. The translation is adequate on the whole, but shows some blemishes which would have been removed had it been revised by a zoologist.

E. S. Russell.

Whales and Modern Whaling. By James Travis Jenkins, D.Sc. Ph.D. [Pp. 239, with 22 plates.] (London: H. F. G. Witherby, 1932. Price 12*s* 6*d*. net.)

Dr. Travis Jenkins follows up his interesting book, *A History of the Whale Fisheries*, with the present work dealing with "the Mammalian order Cetacea and the probable influence of man's persistent hunting on the future of the stock." A large part of the volume treats of the methods for protection of the whales, and much detailed information is given as to the present state of affairs. Even now, when there are many restrictions and indiscriminate fishing no longer is permitted, there still appears to be a danger of depletion by killing the females too young. Whales are usually mature at two years old and a calf is born every two years. Thus the female should be allowed to live for at least four years after maturity in order that the whale population may be maintained.

Much research has recently been made, and is still going on, into the biology of whales, especially those of commercial importance, and we now know a fair amount about the life-histories of these. Workers on the *Discovery* expeditions have tried marking experiments, a very difficult undertaking, which are now beginning to give some good results, marks with shafts being shot into the blubber, the marks remaining whilst the shafts are broken off. Less is known of the smaller whales, of little or no importance commercially, most of the information of necessity coming from those stranded on the coasts. Records of these have been kept for many years at the British Museum. The present work gives instructions for making such records and shows how to identify the species. Chapter IX deals with these lesser whales, including the dolphins and porpoises, Chapters II to VIII give good detailed accounts of the large commercial whales with notes on their fisheries. Chapter I contains a general survey of their natural history, including a simple and clear account of structure, food, and habits.

The whole book is illustrated with photographic plates of the whales themselves and their fisheries, with a few text figures showing the anatomy. It is a most useful contribution to our knowledge of the group and a great help to all who are interested in whales, both layman and scientific worker.

M. V. L.

Methods of Social Study. By Sidney and Beatrice Webb. [Pp. vi + 263.] (London: Longmans, Green & Co., 1932. Price 8*s*. 6*d*. net.)

This book does not claim to be a treatise on the methodology of the social sciences, nor is it an apologia for them. Sidney and Beatrice Webb have set

out the methods which they have used with such conspicuous success in their studies of Trade Unionism, Consumers' Co-operation, and Local Government. But in doing this they have done much more. They have written a really valuable book on methodology, which is an adequate defence of the social sciences against the rather impatient criticisms to which they are now so frequently submitted.

This book, therefore, should provide interest and enjoyment to several classes of readers. The trained natural scientist, who has an interest in contemporary affairs and is inclined to the view that a panel of "real" scientists could quickly put the world to rights, will find, simply set forth in this volume, the intractable nature of the material with which his co-workers in the field of the social sciences have to deal. He will appreciate the difficulties in accumulating data, and above all the very slow and laborious stages through which the various instruments of social science are being fashioned. Such indispensable tools as Questionnaires, reports of Royal Commissions, and Official Statistics, the very test tubes, beakers, and thermometers of the social sciences, turn out to be highly specialised instruments, which have to be remade almost *ab initio* for each particular experiment. But in the early chapter on the Mental Equipment of the Social Investigator, the natural scientist will find an echo of his own ideal which should increase his interest in the later chapters.

For social scientists at large this book should be indispensable. They will find in it constant reminders of the pitfalls that visit them in carrying out even apparently straightforward enquiries. Constant references to Chapters III–X inclusive should prevent much wasted effort. This is the chief objective of the authors, who conclude their Preface: "If students and investigators find the volume helpful, our aim will have been attained. Any of them wishing further explanations are invited to communicate with one or other of us" It is to be hoped that fruitful use will be made of this singularly generous invitation.

Perhaps, however, the most valuable purpose that this book will serve will be to compel university teachers in the social sciences to reconsider the thoroughness of the training which they give to younger research students. It is clear from the description which this book gives of the very thorough-going methods adopted by Beatrice and Sidney Webb in such things as "Note-taking" and "Watching the Institution at Work" that it is not possible under existing conditions to give really adequate training in methods of research at the great majority of our universities. The reason is mainly financial. We cannot afford to train research students in methodology, in sifting evidence and elucidating facts, unless there is also some ultimate gain to be obtained as a result of their enquiries The result is that strict methodological training is usually secondary to the result of the enquiry, and both things suffer in the process. The book makes it clear that if the universities are to do adequate research in the social sciences, they must be more efficiently equipped with material, and with research personnel, so that in the early years of post-graduate work, it will be possible to provide the needful methodological training for the research student. If this is not possible, much of the work done in the social sciences will fall short of the high standard necessary, a standard which has been reached by Beatrice and Sidney Webb in their own studies.

N. F. HALL.

BOOKS RECEIVED

(Publishers are requested to notify prices)

Vector Analysis. By H. B. Phillips, Ph.D., Professor of Mathematics Massachusetts Institute of Technology. New York: John Wiley & Sons, Inc. London: Chapman & Hall, Ltd., 1933. (Pp. viii + 236, with 62 figures.) Price 15*s*. 6*d*. net.

An Introduction to the Calculus for Science Students. By G. van Praagh, B.Sc. (Lond.), Ph.D. (Cantab.), Assistant Master, Perse School, Cambridge. London: Macmillan & Co, 1933. (Pp. v + 92, with 27 figures.) Price 2*s*. 6*d*.

Principles of Descriptive Geometry. By E. L. Ince, M.A., D.Sc., Lecturer in Mathematics in the Imperial College of Science and Technology. London: Edward Arnold & Co., 1933. (Pp. viii + 152, with 153 figures.) Price 8*s*. 6*d*. net.

General Mechanics. Being Vol. I of "Introduction to Theoretical Physics." By Max Planck, Professor of Theoretical Physics, University of Berlin. Translated by Henry L. Brose, M.A., D.Phil. (Oxon.), D.Sc. London: Macmillan & Co., 1933. (Pp. ix + 272, with 43 figures.) Price 12*s*. net.

The Measurement of Air Flow. By E. Ower, B.Sc. (Lond.), A.C.G.I. Second Edition, revised and enlarged. London: Chapman & Hall, Ltd., 1933. (Pp. viii + 243, with 85 figures.) Price 15*s*. net.

Elements of Optics. By Joseph Valasek, Ph.D., Associate Professor of Physics, University of Minnesota. Second Edition. New York and London: McGraw-Hill Book Co., Inc., 1932. (Pp. xv + 254, with 146 figures.) Price 13*s*. 6*d*. net.

The Expanding Universe. By Sir Arthur Eddington, M.A., D.Sc., LL.D., F.R.S., Plumian Professor of Astronomy in the University of Cambridge. Cambridge: at the University Press, 1933. (Pp. vii + 128.) Price 3*s*. 6*d*. net.

The New Background of Science. By Sir James Jeans, M.A., D.Sc., Sc.D., LL.D., F.R.S. Cambridge: at the University Press, 1933. (Pp. viii + 303, with 1 plate.) Price 7*s*. 6*d*. net.

An Outline of Atomic Physics. By Members of the Physics Staff of the University of Pittsburgh. By Oswald H. Blackwood and six others. New York: John Wiley & Sons, Inc. London: Chapman & Hall, Ltd., 1933. (Pp. vii + 348, with 48 figures.) Price 21*s*. 6*d*. net.

A Physics Note-Book. Heat, Light and Sound. By E. W. Tapper, B.Sc., A.K.C., Assistant Master at Dulwich College. London: Methuen & Co., Ltd., 1933. (Pp. viii + 100, with 53 figures.) Price 2*s*.

A Textbook of Physics. Volume II, Heat and Sound. By E. Grimsehl. Edited by R. Tomaschek, D.Phil., Professor of Physics, the University of Marburg. Authorised translation from seventh German edition by L. A. Woodward, B.A. (Oxon.), Ph.D. (Leipzig). London: Blackie & Son, Ltd., 1933. (Pp. xi + 312, with 225 figures.) Price 12*s*. 6*d*. net.

The Cathode Ray Oscillograph in Radio Research. By R. A. Watson Watt, Superintendent of the Radio Research Station, Slough, J. F. Herd and L. H. Bainbridge-Bell, Scientific Officers. London: H.M. Stationery Office, 1933. (Pp. xvi + 290, with 17 plates.) Price 10*s*. net.

Wireless Telegraphy and Telephony. By W. Greenwood, B.Sc. (Eng.), A.M.I.E.E., A.C.G.I., Research Engineer, British Broadcasting Corporation, late Wireless Engineer, His Majesty's Signal School, Portsmouth. Second Edition. London: University Tutorial Press, Ltd., 1933. (Pp. viii + 307, with 210 figures.) Price 5*s*. 6*d*.

Alternating Current Electrical Engineering. By Philip Kemp, M.Sc.Tech., M.I.E.E., A.I.Mech.E., Mem.A.I.E.E. London: Macmillan & Co., 1933. (Pp. xi + 595, with 418 figures.) Price 15*s*. net.

Catalysis and its Industrial Applications. By Edward P. Maxted, D.Sc. (Lond.), Ph.D. (Berlin), F.I.C., Special lecturer in Catalysis in the University of Bristol. London: J. & A. Churchill, 1933. (Pp. xii + 530, with 225 tables and 66 illustrations.) Price 36*s*. net.

Hydrogen Ion Concentration and its Practical Application. By Frank La Motte, William R. Kenny and Allen B. Reed. London: Baillière, Tindall & Cox, 1932. (Pp. viii + 262, with 15 figures.) Price 20*s*. net.

The Conductivity of Solutions. By Cecil W. Davies, D.Sc. (Wales), Senior Lecturer in Physical Chemistry, Battersea Polytechnic. Second Edition, revised and enlarged. London: Chapman & Hall, Ltd., 1933. (Pp. x + 281, with 32 figures.) Price 15*s*. net.

Water Purification Control. By Edward S. Hopkins, Principal Sanitary Chemist, Bureau of Water Supply, Baltimore, Maryland. London: Baillière, Tindall & Cox, 1932. (Pp. x + 131, with 35 figures.) Price 10*s*. net.

Physical Chemistry. An Introduction to First Principles. By A. K. Goard, M.A., Ph.D. London: Sidgwick & Jackson, 1933. (Pp. vii + 222, with 25 figures.) Price 5*s*.

Treatise on Sedimentation. Prepared under the auspices of the Committee on Sedimentation, Division of Geology and Geography, National Research Council of the National Academy of Sciences. By William H. Twenhofel, The University of Wisconsin, Department of Geology and Geography, Madison, Wisconsin, and Collaborators. Second Edition. London: Baillière, Tindall & Cox, 1932. (Pp. xxx + 926, with 121 figures.) Price 46*s*. net.

Earth Lore: Geology without Jargon. By S. J. Shand. London: Thomas Murby & Co., 1933. (Pp. viii + 134, with 33 figures and 4 plates.) Price 5*s*. net.

An Introduction to Tropical Soils. By Dr. P. Vageler. Translated by Dr. H. Greene. London: Macmillan & Co., 1933. (Pp. xvi + 240, with 13 figures and 12 plates.) Price 15*s*. net.

Practical Microscopical Metallography. By Richard Henry Greaves, D.Sc., and Harold Wrighton, B.Met., both of the Research Department, Woolwich. Second Edition, revised and enlarged. London: Chapman & Hall, Ltd., 1933. (Pp. xi + 256, with 54 plates.) Price 18s. net.

Modern Theories of Development. An Introduction to Theoretical Biology. By Ludwig von Bertalanffy. Translated and adapted by J. H. Woodger. London: Oxford University Press, 1933. (Pp. x + 204.) Price 8s. 6d. net.

The Meaning of Animal Colour and Adornment. Being a new explanation of the colours, adornments and courtships of animals, their songs, moults, extravagant weapons, the differences between their sexes, the manner of formation of their geographical varieties, and other allied problems. By Major R. W. G. Hingston. London: Edward Arnold & Co., 1933. (Pp. 411, with 40 illustrations.) Price 18s. net.

The History of the Entomological Society of London, 1833–1933. By S. A. Neave, O.B.E., D.Sc., Honorary Secretary, assisted by F. J. Griffin, A.L.A., Registrar, with an introduction by E. B. Poulton, D.Sc., F.R.S., President, and a financial chapter by A. F. Hemming, C.B.E., Honorary Treasurer. London: Published by the Society, 1933. (Pp. xlvi + 224, with 8 plates.) Price 10s. 6d. net.

Theoretische Biologie Vol. I, Allgemeine Theorie, Physikochemie, Aufbau und Entwicklung des Organismus. By Ludwig v Bertalanffy. Berlin: Borntraeger, 1932. (Pp. xii + 349.) Price RM. 18, paper covers; RM. 20, bound.

Cytological Technique. By John R. Baker, M.A., D.Phil., Lecturer in Cytology in the University of Oxford. London: Methuen & Co., Ltd., 1933. (Pp. xii + 132, with 3 figures.) Price 3s. 6d. net.

Blackboard Coloured Diagrams (Biological Series) No. 22, 24 and 25. Rana Temporaria (The Common Frog); Skeleton; Brain and Nervous System. By W. J. Batt, Oundle School. London: Sidgwick & Jackson, Ltd. Price 10s. 6d. each.

Plant Ecology. For the Student of British Vegetation. By William Leach, D.Sc., Lecturer in Botany in the University of Birmingham. London: Methuen & Co., Ltd., 1933. (Pp. vii + 104, with 6 figures.) Price 3s. 6d. net.

The Senses of Insects. By H. Eltringham, M.A., D.Sc., F.R.S. London: Methuen & Co., Ltd., 1933. (Pp. ix + 126, with 25 figures.) Price 3s. 6d. net.

Locust Control. The Locust Outbreak in Africa and Western Asia, 1925–31. Survey prepared by B. P. Uvarov, Sen. Asst., Imperial Institute of Entomology. London: H.M. Stationery Office, 1933. (Pp. 87.) Price 5s. net.

The Action of the Living Cell. Experimental Researches in Biology. By Fenton B. Turck. New York: The Macmillan Co., 1933. (Pp. xi + 308, with 17 figures.) Price 18s. net.

Life and Living. A Story for Children. By E. P. Phillips, M.A., D.Sc., F.R.S. (S. Afr.). Ashford, Kent: L. Reeve & Co., Ltd., 1933. (Pp. xiv + 152, with 38 figures.) Price 5s. net.

Insects. Man's Chief Competitors. By W. P. Flint, Chief Entomologist, Illinois State Natural History Survey, and Entomologist, Illinois Agricultural Experiment Station, and C. L. Metcalf, Professor of Entomology in the University of Illinois. Baltimore: The Williams & Wilkins Company, 1932. London: Baillière, Tindall & Cox. (Pp. viii + 134, with 12 figures.) Price 5*s*. 6*d*. net.

A First Book of Biology. By Mary E Phillips, B.Sc, Biology Mistress, Godolphin and Latymer School, and Lucy E. Cox, B.Sc., F.L.S., Lecturer in Biology, Graystoke Place Training College. London: University of London Press, 1933. (Pp. 270, with 115 figures.) Price 2*s*. 6*d*.

The Mode of Action of Drugs on Cells. By A. J. Clark, B.A., M.D., F.R.C.P., F.R.S., Professor of Materia Medica in the University of Edinburgh. London: Edward Arnold & Co., 1933. (Pp. vii + 298, with 62 figures.) Price 18*s*. net.

The Tides of Life. The Endocrine Glands in Bodily Adjustment. By R. G. Hoskins, Ph.D, M.D., Director of Research, Memorial Foundation for Neuro-Endocrine Research, Research Associate in Physiology, Harvard Medical School. London: Kegan Paul, Trench, Trubner & Co., Ltd., 1933. (Pp. xii + 352, with 6 plates and 6 figures) Price 15*s*. net.

Great Men of Science. A History of Scientific Progress. By Philip Lenard, formerly Professor of Physics and Director of the Radiological Institute in the University of Heidelberg Translated from the second German edition by Dr. H. Stafford Hatfield, with preface by E N. da C. Andrade, Quain Professor of Physics, University of London London: G. Bell & Sons, Ltd, 1933. (Pp. xx + 389, with 62 illustrations) Price 12*s*. 6*d*. net.

Modern Alchemy. By William Albert Noyes, University of Illinois, and W. Albert Noyes, Jr, Brown University Baltimore: Charles C. Thomas, 1932. London: Baillière, Tindall & Cox. (Pp. x + 208, with 17 figures.) Price 17*s*. 6*d*. net.

Primitive Arts and Crafts. An Introduction to the Study of Material Culture. By R. V. Sayce. Cambridge: at the University Press, 1933. (Pp. xiii + 291, with 58 figures.) Price 8*s* 6*d*. net.

Psycho-Analysis and its derivatives. By H. Crichton-Miller, M.A., M.D. (Edin. and Pavia), M.R.C.P, Honorary Director, Institute of Medical Psychology. London: Thornton Butterworth, Ltd., 1933. (Pp. 256, with 3 figures.) Price 2*s*. 6*d*. net.

History, Psychology and Culture. By Alexander Goldenweiser, Ph.D., Professor of Thought and Culture, University of Oregon. London: Kegan Paul, Trench, Trübner & Co., 1933. (Pp. xii + 475.) Price 18*s*. net.

Science and the Humanities. The Use and Abuse of Information. By John L. Myres, D.Sc., D.Litt., F.B.A., Wykeham Professor of Ancient History at the University of Oxford. London: Oxford University Press, 1933. (Pp. 32.) Price 2*s*. net.

Adventures of Ideas. By Alfred North Whitehead, Sc.D., LL.D., F.R.S., F.B.A., Fellow of Trinity College in the University of Cambridge and Professor of Philosophy in Harvard University. Cambridge: at the University Press, 1933. (Pp. xii + 392.) Price 12*s*. 6*d*. net.

The Story of a Billion Years. By W. O. Hotchkiss, Michigan College of Mining and Technology. Baltimore: The Williams & Wilkins Company, 1932. London: Baillière, Tindall & Cox. (Pp. x + 138, with 8 figures.) Price 5*s*. 6*d*. net.

Spices and Condiments. By H. Stanley Redgrove, B.Sc., F.I.C. London: Sir Isaac Pitman & Sons, 1933. (Pp. xviii + 361, with 42 figures.) Price 15*s*. net.

The Place of Minds in the World. Gifford Lectures at the University of Aberdeen, 1924–1926. First Series. By Sir William Mitchell, K.C.M.G., Vice-Chancellor of the University of Adelaide. London: Macmillan & Co., 1933. (Pp. xxv + 374.) Price 12*s*. 6*d*. net.

Scientific Theory and Religion. The World described by Science and its Spiritual Interpretation. The Gifford Lectures at Aberdeen, 1927–1929. By Ernest William Barnes, Sc.D. Camb., Hon. D.D. Aber. and Edin., Hon. LL.D. Glas., F.R.S., Bishop of Birmingham. Cambridge: at the University Press, 1933. (Pp. xxiv + 685.) Price 25*s*. net.

Church Reform. A National Obligation. By G. F. Stutchbury. With Foreword by Dr. Stanton Coit, Minister of the Ethical Church, Bayswater. London: Watts & Co., 1933. (Pp. x + 118.) Price 3*s*. 6*d*. net.

Science and Religion. A Symposium. By Various Authors. London: Gerald Howe, Ltd., 1931. (Pp. viii + 175.) Cheap edition. Price 2*s*. 6*d*. net.

The Evidence of our Senses. By A. W. P. Wolters, M.A., Lecturer in Psychology and Education, University of Reading. London: Methuen & Co., Ltd., 1933. (Pp. viii + 88, with 3 figures.) Price 2*s*. 6*d*. net.

Adjustment and Mastery. Problems in Psychology. By Robert S. Woodworth, Ph.D., Sc.D., Professor of Psychology, Columbia University, Ex-President, Social Science Research Council. Baltimore: The Williams & Wilkins Company, 1933. London: Baillière, Tindall & Cox. (Pp. vi + 138, with 1 figure.) Price 5*s*. 6*d*. net.

Basic German for Science Students. With Vocabulary and English Translations of the German passages. By M. L. Barker, M.A., Ph.D., Lecturer in German, University of Edinburgh. Cambridge: W. Heffer & Sons, 1933. (Pp. xi + 164.) Price 6*s*. net.

SCIENCE PROGRESS

A PIECE OF CHALK

By P. G. H. BOSWELL, A.R.C.S., D.Sc., F.R.S.
Professor of Geology in the Imperial College of Science and Technology

In 1868 Thomas Henry Huxley delivered one of his famous Addresses to working-men at the meeting of the British Association at Norwich. The title he chose was "A Piece of Chalk." No apology is needed for using the same title again after sixty-five years; during this interval, indeed, many lecturers must have flattered Huxley by doing so, for change of opinion concerning the origin of common chalk has been conspicuous among petrological hypotheses.

Professor H. E. Armstrong, in his recent Huxley Lecture,[1] has recalled the pioneer work on Chalk as a chemical substance; and leaves us rather with the feeling that if there is one natural substance of which the constitution is thoroughly understood, that substance is Chalk. Such may be true of the chemistry of Chalk, but as to the geological history of this material, we are not so clear, for it may be said that if the geological column had been surveyed from the early Pre-Cambrian rocks to those of recent age, no formation could have been found about which we really know less. There has, of course, been no lack of speculation as to its origin; for we have, in the case of the Chalk, an example of the usual rule that speculation varies in inverse ratio to real knowledge.

It should not be without interest, therefore, to review the progress of investigation on the Chalk since Huxley's time, and to seek the reason why, after more than sixty years of intermittent research, there are problems still awaiting solution.

In pursuance of the time-honoured geological method of interpreting the past by the study of the present, Huxley explained the formation of the Chalk in the light of the then recently acquired

[1] *Our Need to Honour Huxley's Will*, Huxley Memorial Lecture, 1933. Macmillan & Co., London.

knowledge of the deposits of Globigerina Ooze, which are spread over a large area of the floor of the Atlantic Ocean. The similarity of the chemical composition of the two deposits, and the presence in both of *Globigerina* and other foraminifera, and of the bodies known as coccospheres, coccoliths, rhabdospheres and rhabdoliths (to be referred to later) were cited in support of the argument. Thus the Chalk came to be regarded as a Cretaceous abysmal deposit and the analogue of a modern oceanic ooze, of which one of the chief characteristics is its purely organic nature and freedom from terrigenous sediment (that is, muddy or sandy material derived from continental areas). This view was succinctly expressed by W. H. Carpenter,[1] who said in reference to the globigerina ooze of the Atlantic Ocean, "We may be said to be still living in the Cretaceous Epoch."

The basis of this conclusion was provided by the results of examination of selected specimens of Chalk. It cannot be said that examples that failed to support the idea of fossilized globigerina ooze were purposely not considered, but it would appear that fine-grained types of Chalk were not amenable to the technique of those days. As a result, the coarse-grained varieties, especially those in which the foraminifera could be seen under moderate magnification, came to be described as typical of the deposit as a whole.

In the decades that followed, there must have been many youthful geologists who (like the present writer) had sufficient faith in the written and spoken word to wash down large quantities of Chalk in the hope of finding the supposedly ubiquitous foraminifera. The results being almost invariably disappointing, the tyro would lay his difficulties before one with a wider knowledge of the problem, only to be told that the view that the Chalk was dominantly foraminiferal had been abandoned in favour of a revised version that the fine constituent material was composed of innumerable prisms derived from the breaking-down of the shells of molluscs such as *Inoceramus*. Once more (and here he would feel assured of Professor Armstrong's sympathy) he would wash down bucketfuls of Chalk, only to be disappointed again. This being the case, we may ask what is the present state of our knowledge of this enigmatic material, and in what respects does it differ from its supposed analogue the deep-sea deposit, globigerina ooze.

Huxley commented on the vast area which seemed to have been occupied by the Chalk sea—extending from Ireland to Scandinavia, Germany, Poland and Russia, and southwards into Belgium and the Paris Basin. But in his view of the Chalk he included the

[1] *Proc. Roy. Soc.*, XVII, 1869, p. 193.

limestones of the Alps, of the Crimea and of northern Africa, formations of totally different appearance, containing very different assemblages of fossils, and now believed to have been deposited in a separate basin (the rudiste or hippurite limestone). The fossils found in this limestone are of warm-water sub-tropical character, whereas those found in the Chalk are often suggestive of cooler northern waters, although they may be sub-tropical in part. In Huxley's time, moreover, the fauna of the Chalk had not been investigated in detail Comparative studies, such as would permit subdivision of the thick formation and correlation of the divisions over northern Europe, had not then been attempted.

In 1875–6, a brilliant young Frenchman, Charles Barrois (still fortunately with us as the honoured Professor Emeritus in the University of Lille), published the results of his investigations of the Chalk of northern France, Britain and Ireland, and by a study of the varying fossil-contents in the successive beds of our thousand feet or so of Chalk showed that it was possible to establish a series of "zones," each with its distinctive assemblage which could be traced through Britain and the neighbouring parts of the Continent.

British geologists, stimulated by his example, actively took up the study of the Chalk. A J. Jukes-Browne and others followed the outcrops of the zones, and with W Hill, W. F. Hume and J. J. H. Teall, investigated the microscopical characters of the constituent material. With the admirable palæontological work, leading to accurate zonal delimitation, crowned as it was by the epoch-making work of A. W. Rowe in 1899–1907, we are not here concerned, but mention should be made of the light thrown upon the problem of the depth and character of the Chalk sea by the increased knowledge of its fauna.

The older view that the Chalk was formed under deep, oceanic conditions, similar to the 2,500-fathom depth of the globigerina ooze, was severely assailed, since among the fossils found were crinoids, echinoids, gastropods and lamellibranchs, which, if we are to judge from present-day distribution, inhabited waters only moderately deep. The evidence of the abundant ammonites, belemnites and brachiopods is less certain since two of these groups are now extinct, and of one there are but few living genera. It was realized, also, that the foraminifera, radiolaria, diatoms and sponges yielded no good evidence of great depth, for they live in water of varying depths and are found in sediments of different lithological types, even of shallow-water origin.

Chalk, however, differs from globigerina ooze in the following respects: (*a*) the general absence of material of volcanic origin,

(*b*) the presence of quartz and many other detrital minerals of continental origin, (*c*) the inclusion of flint, (*d*) the rapid lateral passage into rocks of shallow-water origin such as sandstones, bryozoan limestones, etc., (*e*) the higher content of calcium carbonate, (*f*) the fossils, including remains of molluscs, many (such as the gastropods) resembling those of relatively shallow-water habitat, (*g*) the thickness of the molluscan shells, and (*h*) the greater importance of coccoliths, which are much more significant than foraminifera and sometimes make up the bulk of the rock.

The mode of formation of the fine calcareous mud which forms a large proportion of the deposit still remains in doubt. And while it is true that in some restricted layers of the Chalk and at certain localities there is a profusion of foraminifera or prisms of *Inoceramus* or similar shells, these are by no means typical. W. A. Tarr regarded the "cementing" material as so fine-grained as to be effectively amorphous and suggested that it was deposited as a chemical precipitate from saturated sea-water.[1] But J. Johnston, H. E. Merwin and E. D. Williamson [2] showed that all forms of $CaCO_3$ are crystalline, and I. S. Double later found no amorphous material in an intensive investigation of the Upper Chalk. He noted the occurrence of spherical bodies and prisms in addition to fine dusty calcite. Earlier English workers[3] had recorded spheres and cells, sometimes containing minute crystals of calcite, but were unable to identify any of them with the coccoliths that do occur, and doubted whether many of the bodies were derived from even allied organisms.

Such was the inconclusive state of knowledge when G. H. Drew described [4] a remarkable deposit of finely-divided calcium carbonate now being formed off the coasts of Florida and the Bahamas. He came to the conclusion that the denitrifying bacteria which he found to be swarming in the surface waters were instrumental in causing the precipitation of calcium carbonate through the production of ammonia in the course of their life-cycle. But T. W. Vaughan,[5] while not excluding the possibility of the action of bacteria, observed that the surface-waters of many parts of the ocean were saturated with $CaCO_3$, so that, theoretically, precipitation of calcareous mud could be effected without their aid. New light thus appeared to have been thrown on the natural history of

[1] *Geol. Mag.*, LXII, 1925, p. 252.
[2] *Amer. Journ. Sci.*, XLI, 1916, p. 473; *Journ. Geol.*, XXIV, 1916, p. 729.
[3] *Cretaceous Rocks of Britain*, Vol. II, Mem. Geol. Surv., 1906, p. 291, etc.
[4] Carneg. Inst. Washington, Publ. 182, V, 1914, p. 9.
[5] *Journ. Washington Acad. Sci.*, III, 1913, p. 303.

the Chalk, and at long last a shallow-water origin definitely suggested. But, recently, Maurice Black has carried out a thorough investigation of the conditions of formation of this drewite, as it has been called, in the Bahamas, and has discovered that it consists of finely crystallized aragonite, the orthorhombic form of $CaCO_3$, and not calcite, the rhombohedral form It is interesting to note that it is closely associated with abundant calcareous algæ, well-known as rock-builders. Since the fine material of the Chalk is dominantly calcite, our hope that the mode of formation of drewite would afford a clue to that of Chalk has not, for the time at any rate, been realized

The question remains, however, as to whether the fine material of the Chalk was deposited as aragonite, and has subsequently undergone molecular change (such as we know does take place in minerals) to calcite If this has been its history, we might reasonably expect to find portions of the Chalk where the change-over was incomplete ; but none has yet been observed. Since aragonite is known to be often precipitated from warm waters saturated with calcium carbonate, and calcite frequently from cold waters, we may ask whether Chalk is the cold-water analogue of drewite ; but the profusion of coccoliths and rhabdoliths—which are warm-water forms and are not found in cold seas—lends little support to this view.

Recent years have witnessed a revival of interest in the question of the origin of the Chalk as a rock. To Dr. Z. Sujkowski of the Geological Survey of Poland, we owe the most detailed study of the petrology and origin of Chalk yet published.[1] Not only has he been able to study the outcrops of the formation at the surface, but also to examine a complete section of the Chalk from base to top, fortunately furnished by a deep boring at Lublin, in Poland. The Chalk here proved to be 2,800 feet in thickness, by far the greatest development yet recorded, for the deposit is usually about 1,000 to 1,800 feet in thickness in western Europe. The series of beds penetrated by the boring extends from the Albian to the Danian and marks a complete cycle of sedimentation. It begins with a conglomerate of littoral character and ends with deposits showing a gradual shallowing of the sea. The conglomerate is succeeded by Chalk which was deposited in waters that (if one may rely on the evidence of abundant radiolaria) eventually became of considerable depth. Then follows once more Chalk of the usual type.

An interesting feature observed in a great part of the Lublin

[1] *Bull. Serv. géol. Pologne*, VI, 1930, p. 483.

Chalk is a fine stratification, shown by the alternation of more calcareous and more marly beds, which differ in their content of calcium carbonate by as much as 20 per cent. Usually it is possible to distinguish 30 or 35 of these laminæ to the inch; and it is calculated that the entire series of laminated beds comprises about 500,000 of these alternations. What time-cycle is necessary for the formation of each pair of laminæ is not known; nor is any evidence forthcoming as they are traced laterally to the outcrops on the edge of the Chalk basin, since the lamination disappears and Chalk of the usual massive character takes its place. The possible duration of the Chalk epoch, as calculated from data relating to the disintegration of radioactive elements, is referred to later in this essay.

The marly beds of the Lublin Chalk are considered by Sujkowski to resemble the present-day globigerina ooze more closely than does ordinary Chalk, especially as regards the lower part of the ooze. The Chalk of the Lublin boring differs as a whole from that of western Europe, Germany, Poland generally and Russia in the absence of detrital material, the presence of volcanic minerals and phillipsite, the absence or rarity of glauconite, the absence of phosphates, the rarity of macroscopic fossils, the smaller quantity of calcium carbonate (averaging 75 per cent.), the fineness of grain, the preponderance of pelagic organisms and absence of bottom forms, the richness in globigerinæ and radiolaria, and the absence of echinoids, among other features. Thus the resemblance of the Lublin Chalk to a globigerina ooze supports the view that common Chalk is not truly analogous to a modern deep-sea deposit.

Sujkowski found that the fine-grained matrix or cement of the Chalk was largely composed of coccoliths, tiny bodies about 0·01 mm. in diameter, believed to be algæ. Similar bodies, or rhabdoliths, of rather different form, were also met with, and in the marly Chalk they became abundant. They suggest warm-water conditions. Other algæ-like bodies are present in addition, but, although calcareous, the skeletons do not react to polarized light, that is, they appear not to be crystalline. Similar remains have been recorded by Sir John Murray as planktonic in the Atlantic Ocean (*e.g.* at Station 338 of the *Challenger* Expedition). Many of the forms are six- or eight-rayed, others multi-rayed (*Asterolithes*), and still others display various geometrical forms. As already stated, radiolaria are abundant in certain beds of the Polish Chalk.

It should be mentioned here in reference to the white "cementing" material which constitutes the bulk of the Chalk of Europe generally, that one of the reasons for attributing an abysmal origin

to the deposit was its purity, for it often contains over 90 per cent. (sometimes 98 or 99 per cent.) of calcium carbonate. The remainder is made up of authigenic mineral matter, such as flint and iron sulphide, and also detrital terrigenous material consisting of mineral fragments and mud.

Whilst this terrigenous material of the Chalk is usually fine-grained, consisting of identifiable mineral chips and splinters, as well as irresolvable brownish clay, it sometimes includes quartz (and occasionally felspar) in the form of grains reaching as much as 1 mm. in diameter. The quartz-grains are frequently rounded, a feature which E. B. Bailey (in the case of western Scotland) and I. S. Double (in eastern England) attributed to the prevalence of arid conditions on the land-masses which formed the shores of the Chalk sea. Sujkowski, however, from his study of the present-day deposits of the Red Sea, came to the conclusion that similar grains in the Polish Chalk could not have arrived in the Chalk sea as a result of wind-transport, but by the agency of water-currents from maritime sand-dunes. The present writer finds some difficulty in accepting the latter view, for an examination of many hundreds of dune-sands from various parts of the world has established the fact that rounded grains are extremely rare, and the average diameter rarely exceeds 0·3 mm. It would appear that only under actual desert conditions are spherical grains commonly produced, and in that case, as is well-known, only the large grains become rounded.

The Polish investigator makes a good point, however, when he argues that the grains are too large to have been carried for considerable distances by wind, and that rapid surface-currents in the sea were the probable transporting agents But grains of this diameter would require very powerful currents indeed to be carried far out from the littoral area of shore and wave drift, in which they find their natural home. Moreover, they are accompanied in the Chalk by much finer angular mineral material, and are distributed throughout the calcareous mud itself. One would rather suggest that they were buoyed up by flocculent masses of filamentous algæ, and so carried to the deeper parts of the basin, just as similar grains are maintained in suspension in the estuaries and narrow seas of the present day, to be deposited eventually among clayey sediments of very different grade-size. The similar phenomenon observed during elutriation of sediments in laboratories (when tap-water inconveniently carries algal strands) is familiar to investigators. The abundance of algal remains in the Chalk, referred to on page 196, suggests that the necessary flocculent organic material was likely to have been present in the waters of the Chalk sea.

The scarcity of detrital material in the Chalk, despite the fact that the shores of the Chalk sea were known to lie at no great distance (in Ireland, Scotland and parts of Germany), has been explained by postulating a condition of low relief of the land-area. The country is supposed to have been reduced to a peneplaned state by protracted river-erosion, so that the gradients would permit only slight river-transport. A further diminution of carrying-power in the rivers would result from low rainfall under desert conditions.

Attention has been drawn by L. Cayeux in France and I. S. Double in England to the variety of mineral species found among the scanty detrital material that found its way into the Chalk sea. In the Upper Chalk of the east of England, Double identified as many as sixteen mineral species. His list includes many such interesting records as garnet, rutile, zircon, tourmaline, andalusite, staurolite, chlorite, epidote, hornblende, mica, sphene and kyanite. L Cayeux, G. M. Davies, W. F. Hume and others found similar but less varied assemblages, including chromite, augite and apatite, not mentioned above. Such mineral assemblages are typical of "continental," and not volcanic, rocks

Of no less interest than these detrital minerals are the boulders which have from time to time been found in the Chalk. Although they are rare, several pockets of them have been found, notably at Betchworth, in Surrey. I. S. Double has reviewed [1] the occurrences and has described a series of them varying in size up to a diameter of 6 or 7 inches. They consisted of granites, grits, sandstones and quartzites. While their mode of transportation into the Chalk sea is a matter of conjecture, possible agents being floating ice, tree-roots and seaweed, carriage by icebergs or floes seems, on the whole, most probable. In passing, it may be noted that several of the boulders have ill-defined annelid tubes and bryozoa attached to them.

That there should have been divergent views regarding the depth of the Chalk sea is only to be expected in view of the changing ideas of origin of the Chalk. On the one hand, we find that Jukes-Browne, Hill and others favoured depths extending from 300 to 1,000 fathoms (although on the whole they thought the smaller depths more probable), and on the other, L. Cayeux was convinced that the Chalk of the Paris Basin was formed under a sea not deeper than 180 fathoms. W. A. Tarr, in speculating on the depth of water in which the Chalk might have been precipitated chemically, places it at less than 400–500 fathoms, and sees no reason why it should not have been less than 20 fathoms.

[1] *Geol. Mag.*, LXVIII, 1931, p. 65.

It is now generally agreed that the depths of the Chalk sea varied, and that the lower part of the Lower Chalk and the bottom beds of the Upper Chalk (the Chalk Rock) were deposited under conditions shallower than those under which other parts of the formation were accumulated. Evidence is provided by the molluscs, particularly the gastropods, which are common in the Lower Chalk and in the Chalk Rock. H. Woods [1] discussed the conditions under which the Chalk Rock was deposited and concluded that it was formed in a sea of a depth between 100 and 150 fathoms, but nearer the former than the latter.

C. P. Chatwin [2] has investigated a series of gastropods found inside sea-urchins in the Norwich Chalk, and concludes that such an assemblage lived in water that was probably not much deeper than 100 fathoms. Remains of gastropods similar to those found in the Chalk Rock have subsequently been found inside sea-urchins of higher horizons in the Chalk. It would thus seem that the finding of such organisms is largely dependent on preservation.

The greater depths previously mentioned were based on the false analogy of the Chalk and globigerina ooze. But the influence of this false analogy has lingered long and its cramping effects can be detected in most discussions on the bathymetrical conditions of the Chalk sea. One cannot avoid the suspicion that conclusions as to the evidence of fossils would have been stated more boldly in favour of shallow depths but for considerations of the early globigerina ooze analogy. We may therefore summarize the present position by saying that the evidence of cross-bedding, of the echinoids and lamellibranchs, and particularly of the gastropods, suggests a moderate depth of about 200 fathoms.

One further feature of the Chalk remains to be noted. Huxley, in his 1868 Address, referred to the long duration of the Chalk epoch and graphically described examples of "corallines" (bryozoa) which had grown on dead shells of the bivalve *Crania*, which in turn were attached to the tests of *Micraster*. Thus he brought home to his audience the realization of the extreme slowness of deposition of the Chalk, for the *Crania* and bryozoa in turn each endured their life-cycle before the echinoids were finally covered with calcareous mud. A further proof of slowness of deposition is afforded by the gastropods of the Norwich Chalk. Most of them were found inside the tests of sea-urchins, and the fact that in many cases the gastropods were larger than the apertures of the sea-urchins shows that they must have lived, grown and died within the empty test

[1] *Quart. Journ. Geol. Soc.*, LIII, 1897, p. 402.
[2] *Naturalist*, 1923, p. 401.

before that test became filled with chalky ooze.[1] As a parallel we may cite the exceedingly slow accumulation of deep-sea oozes, which sometimes barely cover the teeth of sharks long extinct.

In his discussion of the Polish Chalk, Sujkowski calculated that in a portion only of the formation at Lublin 500,000 rhythmic bands are present. Each rhythm marks a period of time of unknown length, but it is unlikely to be less than annual (seasonal rhythms). For the deposition of the whole of the Chalk, a period greatly in excess of 500,000 years is thus adumbrated. In the case of the mud of deltas, a deposit which is probably formed much more rapidly than Chalk, the average rate of accumulation has been estimated at one foot in 300 to 1,000 years. At the same rate the Chalk must have taken over a million years to form, but there are sound petrological reasons which justify our increasing this figure considerably. Our only other line of argument is afforded by the evidence of the disintegration of radioactive elements. The general tables published of the geological time-scale based on this method of estimation [2] indicate a figure of about 30 million years for the Chalk epoch. This would mean an average rate of deposition of 1 foot of Chalk in about 10,000 years.

Of the familiar flints in the Chalk, considerations of space do not allow us to speak. Another essay could be written on "A Piece of Flint," an equally interesting subject, but that must await another occasion.

Such, then, is a summary of the present state of our knowledge of a commonly-occurring and so-called "well-known" rock—a piece of Chalk. We see that it provides a study as fascinating to-day as in Huxley's time; but we are less disposed than our geological forebears to dogmatize on its origin and affinities, and we continue to marvel, still seeing only as through a glass darkly.

[1] C. P. Chatwin, op. cit.

[2] A. Holmes, *Journ. Washington Acad. Sci.*, XXIII, 1933, p. 169.

THE HYDROGEN ISOTOPE OF MASS 2

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Among new fundamental entities the discovery of which has so astonished the scientific world during the last few years the one which may well have the earliest and most remarkable technical applications is the heavy isotope of hydrogen. The story of its discovery is an interesting one. Precision measurements of the packing fraction of normal hydrogen made by means of the mass-spectrograph and published in the Bakerian Lecture of 1927 showed that its atom had a mass of 1·00778, a figure identical with its chemical atomic weight. After the discovery and confirmation of the presence of heavy isotopes in oxygen, Birge and Menzel pointed out that to bring these results into accord hydrogen also must contain heavy isotopes. The discrepancy was only about one-fiftieth of a per cent., but a search was carried out by Urey, Brickwedde and Murphy, and after concentration by continuous fractionation of liquid hydrogen they were able to demonstrate the presence of an isotope of mass 2 in the enriched residues by optical analysis of the Balmer lines.

Their discovery was announced in 1932 and since then development, which has been almost entirely due to American research workers, has proceeded with almost bewildering rapidity. The ratio between the masses of the two types of hydrogen is unique among isotopes, and quantum mechanics suggests comparatively easy separation by simple electrolysis. This process has been investigated by Washburn at Washington who described results according well with the theoretical predictions at the recent scientific congress at Chicago where numerous other papers bearing on the new type of atom were also read. The most successful concentrations by electrolysis have been achieved by Lewis at Berkeley, who has obtained a fraction of a cubic centimetre of heavy water H^2H^2O calculated to contain less than 0·01 per cent. of normal hydrogen. Lewis reports that this fluid, which has an appearance indistinguishable from ordinary water, has a density of 1·1056 at 25° C., boils at 101·42°, freezes at + 3·8° and has a maximum density at 11·6°.

Its heat of vaporation is 259 cal. per mole greater than that of ordinary water. These figures are a rather pathetic reflection on the implicit trust of the savants who founded our system of physical units in the constancy of the properties of that fluid, and are a striking illustration of the fallibility of our most carefully selected standards.

Making use of enriched samples of hydrogen supplied by Urey, Bainbridge measured with his mass-spectrograph the isotopic weight of H^2 soon after its discovery by direct comparison of the line of the triatomic molecule $H^1H^1H^2$ with that of He^4; his most reliable value is 2·0136. The use of the new isotope in controllable quantities will be of the utmost value in establishing the positions of the lighter atoms on the physical scale of mass. Already Bainbridge has determined the isotopic weights of the isotopes of lithium by this means to a much greater degree of certainty than hitherto possible.

Heavy hydrogen nuclei have been used as an alternative to protons for producing nuclear disintegrations. In the experiments of Lewis, Livingstone and Lawrence diatomic ions H^1H^2 produced from water containing 50 per cent. of H^2 have been accelerated in the ingenious synchronous acceleration apparatus devised by Lawrence. Mixed beams with energies of about a million volts produced in this way have been directed upon various targets with remarkable results. A lithium target, in addition to the ordinary results expected from proton bombardment, gave off alpha particles of the unprecedented range of 14·5 cm. It appears practically certain that these are due to the transformation of H^2 and Li^6 to give 2 He^4. With beryllium as a target the two types give the same species of alpha rays but with high energies the heavy nuclei are a hundred times more efficient than protons. The bombardment of targets of heavy elements always resulted in the production of high-speed protons in large numbers, some with ranges up to 40 cm.

At the recent meeting of the Physical Society at the Cavendish Laboratory, Lord Rutherford exhibited a small sample of heavy water generously presented to him by Lewis, and described experiments now in progress made by himself and Oliphant in which they had confirmed and extended the work of Lawrence by the use of homogeneous beams of heavy hydrogen nuclei of lower voltages but enormously greater intensity.

The abundance of H^2 present in ordinary hydrogen is still uncertain. At first it was thought to be about 1 in 4,000, but later experiments on the intensity of infra-red spectra of hydrochloric acid suggested only one-eighth this abundance. There seems, how-

ever, some doubt whether the sample used was a fair one, so that it is possible that the abundance is sufficient to account for the discrepancy which led to its discovery. A critical search for an isotope of mass 3 has shown beyond doubt that this does not exist even to the extent of one part in several millions.

It is highly desirable that means should be developed in this country to obtain without delay an adequate supply of this remarkable substance, for its potentialities in chemistry, particularly in organic chemistry, really merit the word sensational The possibilities of five different methanes and innumerable variations of more complex molecules are obvious, to say nothing of new modes of attack on such problems as optical activity. Furthermore substitution of H^2 for H^1 possible in the molecule is equally so in the living cell and its extension through bacteria and tadpoles to man may be safely left to the imagination of the reader. We have before us a new chemistry and a new biology.

Several names have already been suggested for the new body, but any decision must be most carefully considered, as the difficulties of nomenclature it raises are quite unprecedented. It has a Moseley atomic number 1, so is certainly hydrogen and not a new element in the accepted meaning of the term. On the other hand it is unlike any other isotope, for it can be separated and used as a pure reagent, so that for the convenience of chemistry it must be given a name to distinguish it from normal hydrogen. It is also desirable that its nucleus should be given a definite name for comparison of its physical effects with those of protons and alpha particles.

RADIO RESEARCH IN AUSTRALIA[1]

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Radio communication and radio broadcasting in particular are of peculiar importance in the continent of Australia owing to the sparseness of the population, the large distances involved and the isolated conditions under which many people are obliged to live. The Council for Scientific and Industrial Research of the Commonwealth has accordingly established a Radio Research Board and some of the results of the investigations into the propagation of waves and atmospherics which it has conducted are contained in the bulletins enumerated below. The work has been mainly concerned with the influence of the ionised layers of the upper atmosphere, using the experimental methods developed in this country by Professor Appleton and his collaborators, and apart from its local applications it may be regarded as providing a valuable confirmation of their conclusions and a useful extension of our knowledge of the nature of these layers in different parts of the globe.

Among the peculiar phenomena experienced in wireless transmission are the differences between day and night transmission, the bending of long waves round the earth, the fading of medium-

[1] Radio Research Board, Australia, *Report No 2.* 1. The State of Polarisation of Sky Waves. 2. Height Measurements of the Heaviside Layer in the Early Morning. By A. L. Green, M.Sc.

Report No. 3. The Influence of the Earth's Magnetic Field on the Polarisation of Sky Waves. By W. G. Baker, B.E., B.Sc., and A. L. Green, M.Sc.

Report No. 4. 1. A Preliminary Investigation of Fading in New South Wales. By A. L. Green, M.Sc., and W. G. Baker, B.E., B.Sc. 2. Studies of Fading in Victoria : A Preliminary Study of Fading on Medium Wavelengths at Short Distances. By R. O. Cherry, M.Sc., and D. F. Martyn, Ph.D., A.R.C.Sc. 3. Studies of Fading in Victoria : Observations on Distant Stations in which no Ground Wave is received. By R. O. Cherry, M.Sc.

Report No. 5. Atmospherics in Australia.—I. By G. H. Munro, M.Sc., A.M.I.E.E., and L. G. H. Huxley, M.A., D.Phil.

(Melbourne, 1932.)

wave signals, the phenomenal ranges attained with short waves, and the "night errors" of wireless direction finders. It is now common knowledge that these anomalies are due to waves returned to the earth from the upper atmosphere, but the idea of a definite surface reflecting wireless waves as a mirror reflects light is too simple to fit the facts True reflection can only take place when an appreciable change in the properties of the medium occurs within a distance of less than one wavelength. Actually a layer consists of a region where the density of the ionisation falls away more or less gradually above and below the height at which it is a maximum. In the absence of collisions between the ions such a medium will behave as a perfect dielectric having a dielectric constant and refractive index less than unity, the phase velocity of an electromagnetic wave being greater than that in free space. A ray entering the layer from below will therefore be bent forward and downward until it leaves the layer again at the same angle as that at which it entered, thus behaving as though it had been reflected from a surface situated at a height rather greater than the maximum height actually attained by the ray. It is the height of this fictitious reflecting surface which is known as the "equivalent height" of the layer, and apart from variations in the layer itself the value of the equivalent height will in general be slightly different for different angles of incidence as well as for different wavelengths; moreover, it may be above or below the level of maximum ionisation.

The reduction of refractive index produced by a given amount of ionisation is less for high frequencies than for low frequencies. It can be shown that for a ray to undergo sufficient deviation to be returned to earth a definite density of ionisation must be attained, this being greater for short wavelengths and small angles of incidence. For example, a layer of maximum density 10^5 electrons per c.c. (a typical value) will return all wavelengths greater than 100 metres no matter what their angle of incidence, but at wavelengths less than this the rays near the vertical will penetrate the layer, the minimum angle of incidence required for the ray to be returned becoming greater and greater as the wavelength is reduced. At short wavelengths the direct ray along the ground is rapidly absorbed, so that we get the remarkable phenomenon known as "skip distance," no signals being received at distances less than that at which the sky waves begin to arrive.

The assumption that the ionised medium behaves as a pure dielectric is only justified if the ions can execute their motions unimpeded under the influence of the electromagnetic field of the wave, whereas in fact they lose energy from time to time through collisions with gas

molecules. This loss is unimportant when the period of the oscillations is small compared with the time between collisions, but when this is not the case absorption of the wave will occur. This absorption will be most marked when ionisation is to be found at low regions of the atmosphere where the pressure is high. For a given path it will be greatest for long wavelengths, but no general conclusions can be drawn from this as the long waves will not penetrate so far into the layer as the shorter ones.

The agency producing the ionisation is solar radiation. During daylight there will tend to be an equilibrium at any given height between the rate of production of ions and their rate of recombination. The latter depends on the pressure, and equilibrium will be established most quickly at the lowest levels where the rate of recombination is greatest. During the day, therefore, the ionisation will be not only more intense as a whole but also relatively more intense in the lower regions.

Theoretical and experimental evidence now points to the existence of three main regions of ionisation which have been designated by Appleton the D, E and F regions The lowest or D region has its maximum intensity at a height of some 50 to 60 km., and owing to the comparatively high pressure at this level its action on the medium wavelengths used for broadcasting is to absorb the upward radiation, thus preventing it from reaching the upper reflecting layers during the daytime. The high rate of recombination at this height leads to its rapid disappearance after sunset. The middle region or E layer situated at a height of about 100 km. constitutes the Kennelly-Heaviside layer proper and is responsible for most of the reflection of broadcast waves which occurs during darkness. In England it was found that this layer rose slowly during the night from about 100 km. to an average of 126 km. owing to recombination and then fell rapidly by the same amount at sunrise, after which the formation of the absorbing D layer prevented further measurements on the broadcast wavelengths. In Australia, however, the height usually remained constant at about 110 km. throughout the night. The upper region or F layer, known also as the Appleton layer, is found at heights varying from 200 to 350 km. or more. It is only in evidence when the ionisation of the E layer is small enough to allow the waves to penetrate, which sometimes happens on the broadcast wavelengths in the hours just before dawn. The existence of this upper layer was at first disputed; its equivalent height is often about twice that of the E layer, in which case the experimental results can be explained in terms of a double reflection from the latter. Such multiple reflections do in fact occur, but the

reality of the F layer seems nevertheless to have been definitely established.

The action of the ionised layers in producing fading of broadcast signals at night can be illustrated by reference to the results obtained in Australia. Investigations at distances between 65 and 200 km. from the transmitting stations showed that the main type of fading had a period of from one to five minutes. This was due to interference between the direct wave along the ground and the reflected wave from the E layer, the changes in the length of path of the latter causing it to be alternately in and out of phase with the ground wave. Results obtained at distances between 590 and 870 km., beyond the range of the ground wave, showed a slow fading having an irregular period ranging from two to thirty minutes, this being put down to changes in the intensity of a single ray from the E layer. In both cases there were frequently found superimposed on the slow changes quicker variations of small amplitude having periods ranging from five to thirty seconds, and these were regarded as being due to interference between the main radiation and a wave returned from the F layer.

The propagation of waves in the ionised regions is considerably modified by the earth's magnetic field. The wave radiated from a transmitting aerial is of course plane polarised, but after deviation by an ionised layer it will be found elliptically or circularly polarised. Appleton and Ratcliffe found the polarisation to be circular and left-handed for a transmission from south to north in England, and suggested that, for similar conditions of transmission towards the pole in the Southern Hemisphere, the polarisation should be circular and right-handed. The workers in Australia have confirmed this prediction and have moreover developed a theory by means of which the polarisation of a ray coming down in any direction can be calculated.

Interesting results have also been obtained from investigations of atmospherics by means of the cathode ray direction finder. The atmospherics received during a voyage from England to Australia were found to originate in certain well-defined areas, notably one in central Africa, known to be the most active thunderstorm area in the world. The observations definitely indicate a lightning stroke origin for all the atmospherics observed. It has also been found that all atmospherics are of comparable intensities at their source, so that from a knowledge of the rate of attenuation the distance of a source can be estimated from the intensity of the disturbance received. It is anticipated that observations of atmospherics will prove of value in forecasting weather conditions.

THE X-RAY INTERPRETATION OF FIBRE STRUCTURE

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When we investigate the structure of matter by the methods of X-ray analysis, fundamentally it is only a question of using the eyes of physical apparatus and the brain of theoretical physics to examine objects which fall below the limits of human vision. There is no essential difference in theory between X-ray analysis and vision, however dissimilar they may appear in actual practice, for both depend on the scattering or " diffraction " of ether waves by the bodies under examination, followed by recognition of the form of the diffracting bodies from that of the diffracted waves. For ordinary vision we use the so-called " visible " light, the wave-lengths of which extend from about 4000 Å.U.[1] to about 8000 Å.U.—that of yellow light, for instance, being 5893 Å.U.—and the form of the waves which enter the physical apparatus of the eye is " interpreted " automatically, if the experimenter has no anatomical defect and is in his right mind, as something we are accustomed to think of as the " truth " but which, frequently enough, is nothing of the sort. Similarly, for the requirements of X-ray analysis [2] we use one of the kinds of " invisible " light, the ether waves of short wave-length called X-rays. These do not excite the sensation of vision when they fall on the retina of the eye, but they may be registered photographically or by other physical means, and once more it is possible from the strength and directions of the scattered waves to visualise the bodies which scattered them—provided again that both experimental and mental technique are sound!

[1] An Ångstrom unit of length (1 Å.U.) is one-hundred-millionth of a centimetre.

[2] X-ray analysis must not be confused with the radiology or radiography of hospital practice, which is only a form of " shadowgraphy " depending on the fact that X-rays have the power of penetrating bodies which may be opaque to visible light.

The object of using X-rays instead of visible light is, of course, to extend the range of vision, that is to say, to permit us to view—mentally, at least—objects which are far too small to be seen by the human eye, even with the aid of the most powerful microscope. Just as ripples are seriously distorted by pebbles which would be far too small to affect the main form of ocean waves, so X-rays, some ten thousand times shorter in wave-length than visible light, are seriously distorted by atoms and molecules which are far too small to disturb the main form of waves of visible light. We "see" things through the waves which are thrown back from them, and we can distinguish only such irregularities as are not much smaller than the wave-length of the waves used, because irregularities which are negligible compared with the waves make negligible impressions on them. By using smaller and smaller wave-lengths we can detect

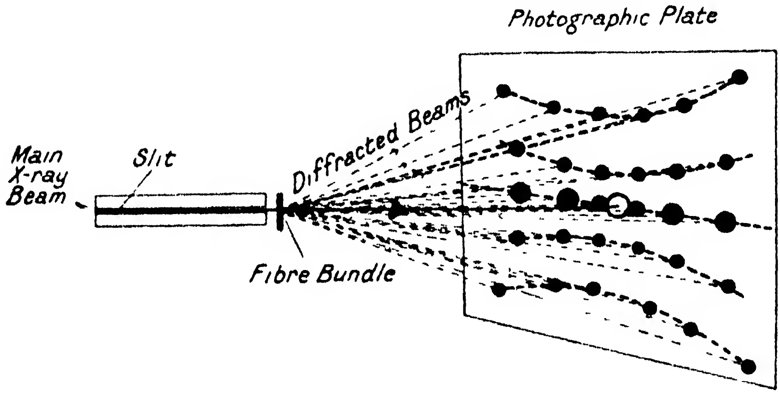


FIG. 1.—To show diagrammatically the essentials of taking an X-ray fibre photograph

smaller and smaller irregularities till finally, in the "light" of the X-rays, we can distinguish, after making the appropriate calculations, the shapes of the atoms and molecules themselves.

A drop of water, for example, when tested with a fine beam of monochromatic, or approximately monochromatic, X-rays[1] is shown to have a grained structure, to be built up, in fact, of "particles," which we identify with the actual water *molecules*, at a certain average distance apart. The X-ray photograph in this

[1] The experimental arrangement for all the X-ray photographs described or illustrated in this article is comparatively simple: it is shown diagrammatically in Fig. 1. The "slit" used for defining the X-ray beam is a cylindrical metal tunnel, about 4 cm. long and ½ mm. in diameter, while the photograph is recorded on a quarter-plate or film set normal to the beam and a few centimetres from the specimen under examination. For the photographs shown the X-ray wave-length was 1·54 Å.U. (the K-radiation from a copper anti-cathode). The main beam after passing through the

case is little more than a single broad halo like that shown in Fig. 2*a* (a photograph of a piece of unstretched india-rubber), and the experiment is analogous to the formation of the corona when a cloud passes in front of the moon, or when a light is viewed through a misty window-pane. Just as from the size of the corona we can calculate the average size of the water-drops in the cloud, so from the size of the diffuse ring on the photographic plate we can form an estimate of the average distance of separation of the water molecules in the liquid drop. An X-ray photograph of this kind may be called an "amorphous" photograph: it is typical of liquids and gases, because in such states of matter the molecules have no permanent regular arrangement, *but of very few solids.* One of the solids that give an amorphous X-ray photograph is glass, while another is ordinary unstretched india-rubber (Fig 2*a*, Plate I): from the latter we may infer the most probable distance of separation of the long chains of polymerised isoprene $(C_5H_8)_n$, which form the bulk of the rubber substance.

If now we stretch the elastic band photographed in Fig. 2*a* (Plate I) to several times its original length, then take another photograph under similar conditions, we obtain a totally different result (Fig. 2*b*, Plate I). The new photograph is obviously more specialised and informative; it is a pattern constructed, not merely of a single diffuse ring, but of a considerable number of "spots," a regular diffraction pattern which is telling us that stretched rubber is in a higher state of organisation than unstretched rubber, is in fact "crystalline," as we say

Thus, as we should expect from our knowledge of vision and visible light, an X-ray photograph is a diffraction picture portraying, though indirectly, the state of organisation of the body photographed, and what is more, the state of *molecular organisation.* The X-ray diffraction photograph of any substance is characteristic of that substance; it is a "molecular passport photograph," so so speak: though it resembles nothing that can be seen by eye, it is the physical basis of the mental picture we form, after making the necessary calculations, of the invisible molecules.

From the point of view of X-ray analysis it is most convenient to think of the molecular organisation of a material structure in terms of its state of crystallisation. The crystalline state may be

specimen would make a large black spot at the centre of the photograph were it not blocked out by a small lead disc mounted immediately in front of the plate This explains the white spot at the centre. The X-ray photograph proper consists of the black rings, arcs, or spots, symmetrically disposed about the central white spot.

fairly called the "natural" state of solid matter, for there is an almost universal tendency among molecules to settle down during the act of solidification, not in irregular heaps, but in regular and often highly symmetrical aggregates—crystals—which are simply three-dimensional, or space-, patterns analogous in every way to the familiar flat, or two-dimensional, patterns of wall-paper or textile fabrics. The consequence of this is that if we can deduce from the X-ray diffraction picture—as theoretically we should be able to do—the form and dimensions of the molecular pattern underlying the crystal architecture of the substance which gives rise to that pattern, we are at once in a position to draw conclusions as to the form and dimensions of the molecules themselves, simply because *the dimensions of a pattern are the expression of the dimensions of the units from which it is built.* From X-ray photographs of loose and ill-defined molecular aggregates such as are found in liquids and gases we can deduce only average molecular dimensions ; but from photographs of the regular molecular aggregates which are the crystals of the solid state we can deduce, given sufficient experimental data, detailed dimensions of molecules and the way they fit together Furthermore we have the power by X-ray methods, not only of analysing individual crystals, but also of determining their size and mutual arrangement in a poly-crystalline mass.

At first sight it might appear rather hopeless to apply these ideas to the intimate structure of fibres, since no crystals at all are revealed by direct optical examination ; but we must remember that there is a considerable gap between the limits of ordinary vision and those of X-ray vision, a gap—the world of "colloidal" particles—in which there is ample room for the existence of *sub-microscopic* crystals which must betray themselves immediately to X-ray examination. And this is just what happens in the X-ray analysis of fibre structure ; we see at once that *the molecules of fibres are in general aggregated into crystalline, or pseudo-crystalline, groups*, from the orientation and constitution of which we can draw conclusions of first-rate importance. Figs. 3*a*–*e* (Plates I and II) are typical X-ray "fibre photographs," as they are called, taken after the manner shown diagrammatically in Fig 1. They all indicate the indubitable presence in the fibre substance of matter in the crystalline state, though the state of crystallinity is by no means perfect, for the best X-ray photographs of biological subjects are distinctly "poor" as compared with corresponding photographs of common laboratory crystals. All these fibre photographs have, however, two features in common, namely, similarity of crystal size and shape, and well-defined selective orientation : in other words, they show that *the sub-microscopic crystalline*

aggregates formed by the molecules of fibres are long and thin and lie with their long axes either all roughly parallel to the fibre axis (natural and artificial silks, mammalian hairs and spines), or arranged so as to form a spiral round the fibre axis (ramie, cotton).

From the combined evidence of a mass of physico-chemical and crystallographic data into which we need not enter here, it is now generally agreed—and the conclusion is irresistible—that the molecular aggregates which are disposed so regularly in the body of natural fibres are no other than *thin bundles of molecular chains*, praiseworthy attempts at crystallisation when the fibre molecules, " line-molecules " at least a hundred times as long as they are thick, cling together, or are chemically joined together, all along their lengths. We know that such a process of lateral cohesion takes place readily when the common oils, fats, waxes, etc , crystallise or form surface films, as in lubrication, while it is a commonplace that the physical properties of long-chain compounds show progressive changes as the chain-length increases—for example, the melting-point steadily rises on account of the progressive increase in the total inter-molecular cohesion between each chain and its immediate neighbours. Similarly, the strength of natural fibres is to be ascribed chiefly to the great length of the chain-molecules from which they are built, even as the strength of a textile yarn, other things being equal, depends on the lengths of the individual fibres from which it is spun. There is, indeed, a close analogy throughout between the structure of a textile yarn—an abnormally fat yarn, to be sure, since through the cross-section of a wool fibre, for instance, pass over 500 million molecular chains—and that of the fibres from which it is spun : the yarn is related to the fibre as the fibre to the molecule , in other words, the fibre is a thick *molecular yarn.*

The mechanism of crystal formation within such a molecular yarn through the side-to-side cohesion of long molecules may be illustrated very simply by reference to the structure of a bead curtain. If we think of each string of beads as corresponding to a fibre molecule, the way a three-dimensional molecular pattern, a fibre crystal, may be built up merely by a process of laying the molecules side by side becomes obvious. The pattern in a bead curtain is, of course, only plane, or two-dimensional, but there is no essential difference in principle when we proceed to space patterns. Just as plane patterns arise from the parallel juxtaposition of line patterns, so space patterns arise from the parallel juxtaposition of plane patterns. A regular sequence of parallel bead curtains placed one behind another would thus build up a " bead crystal." We should beware, however, of taking too ideal a view of the interior of

a fibre. It seems best to concentrate on the idea of greatly elongated molecules all lying roughly parallel to the fibre axis (or arranged spiral-wise around it), after the manner of the fibres in a yarn, and then to imagine them aggregated into groups, long, thin chain-bundles, of varying size and perfection, whose boundaries of separation are not at all well-defined. The regular diffraction pattern of the X-ray fibre photograph arises from the more regular of these groups which are thereby made to yield information about the structure of the fibre as a whole and the nature of the individual molecules It is hardly possible here to give crystallographic details, but it will be clear from what has already been said that the X-ray diffraction pattern is a short-wave expression of the molecular pattern, which in turn is the expression of the shape of the molecules and the way they are fitted together. The molecules themselves are line-patterns (see Fig. 4), that is, are constructed by the uni-directional repetition of some *intra*-molecular unit—are "linear polymers" of this unit, we may say—and so the crystal pattern along the length of any single fibre crystal is based on the pattern *within* the molecule, each "repeat" being joined to its immediate neighbours through the intermediary of true chemical bonds On the other hand, the repetition of pattern at right angles to the length of a fibre crystal is a measure of the lateral dimensions of the molecules, which need not necessarily be joined sideways by chemical bonds, the residual attractions which exist between all molecules being amply sufficient with molecules of such extraordinary lengths to explain the great strength observed. It is instructive to compare this structure of the typical fibre crystal with that of some simpler crystalline solid, such as naphthalene The cohesion in all directions throughout the latter is maintained simply by the operation of *inter*-molecular forces, but in the long direction of a fibre crystal we find a continuous sequence of *intra*-molecular junctions, true chemical bonds. When a naphthalene crystal is sublimed or dissolved the structure disintegrates in all directions alike ; but when a fibre crystal is broken up by solvents, there is only a lateral separation of the long molecular chains This is the basis of the artificial silk industry. A viscous solution, for example of cellulose in cuprammonium, is squirted through the holes of a "spinneret" into a coagulating medium : the long, thread-like molecules of cellulose are thereby drawn into alignment and re-precipitated as chain-bundles similar to those found in the native cellulose before solution (cf. Figs. 3*a* and 3*b*, Plate I), except that now, of course, they are embodied in fine filaments of any required length. The process is exactly analogous to the way in which a

silk-worm uses its spinning-gland to make natural silk. X-ray fibre photographs of artificial and natural silk, respectively, are shown in Figs. 3*c* and 3*d* (Plate I): though cellulose is a polysaccharide and fibroin a protein, it is clear from these two photographs that in both cases the fibres are built from sub-microscopic, elongated crystallites packed together so as to lie with their long axes parallel to the fibre axis.

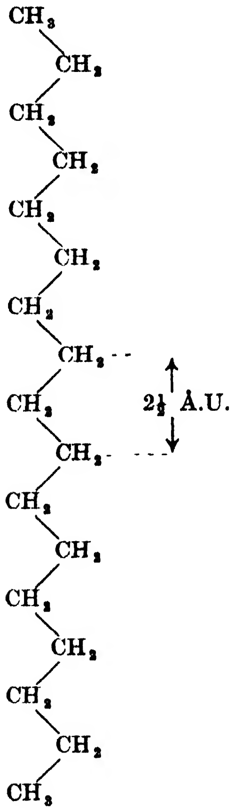


FIG. 4*a*.

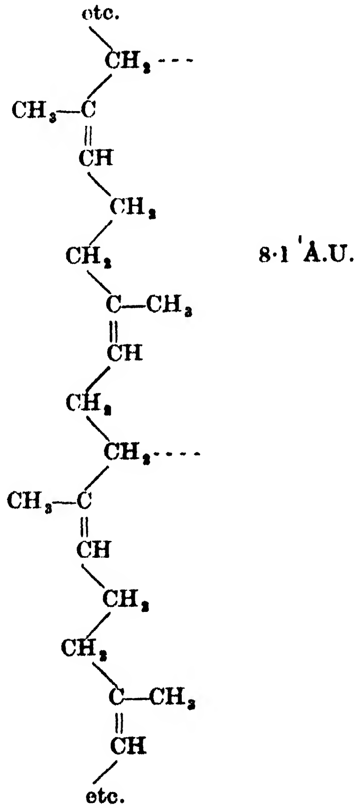


FIG. 4*b*.

FIG. 4.—Chain-molecules: (*a*) The hydrocarbon $C_{17}H_{36}$. (*b*) A short length of the stretched rubber molecule.

The resemblance between the structure of cellulose fibres and that of natural silk extends, however, farther than this, for again *both are built from chain-molecules in a fully-extended state.* This conclusion follows from a comparison of the chemical formulæ given in Figs. 4*c* and 4*d* with the actual dimensions of the molecular patterns as deduced crystallographically from the X-ray fibre photographs. So much is known now from X-ray and spectral studies of

THE X-RAY INTERPRETATION OF FIBRE STRUCTURE

PLATE I

FIG. 2a.—X-ray photograph of an unstretched elastic band.

FIG. 2b. X-ray photograph of the same band stretched to seven times its original length.

FIG. 3a. X-ray fibre photograph of native cellulose (ramie).

FIG. 3b. X-ray fibre photograph of native cellulose (cotton).

FIG. 3c. X-ray fibre photograph of mercerised cellulose (an artificial silk).

FIG. 3d. X-ray fibre photograph of natural silk (fibroin).

PLATE II

FIG. 3e. X-ray fibre photograph of a porcupine quill (α keratin).

FIG. 5a. X-ray fibre photograph of unstretched human hair (α keratin).

FIG. 5b. X-ray fibre photograph of the same hair stretched (in steam) to twice its initial length (β keratin).

FIG. 6a. A cell of the alga *Valonia ventricosa*.

FIG. 6b. The outer surface of the cell wall of the same alga as seen under the microscope. The crossed striations should be noticed.

FIG. 6c. The cell wall of the same alga as photographed by X-rays. The X-ray photograph is really two crossed cellulose photographs (cf. Fig. 3a), the "equators" of which are perpendicular to the crossed striations seen in the photomicrograph (Fig. 6b). The cellulose chains are therefore parallel to the striations.

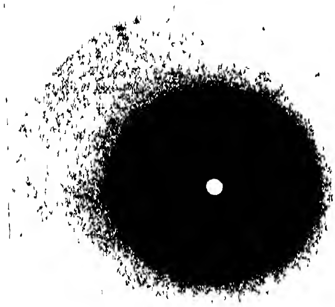


Fig 2*a*

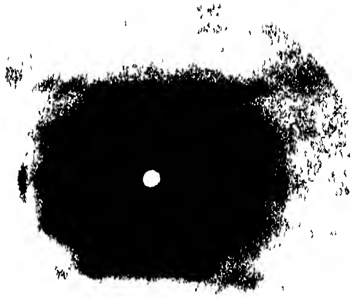


Fig 2*b*

Fig 3*a*

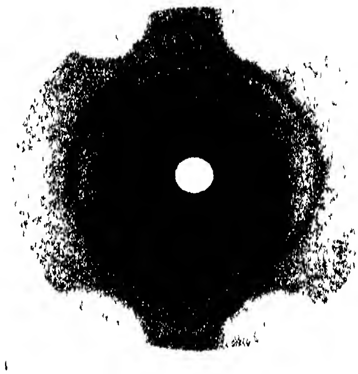


Fig 3*b*

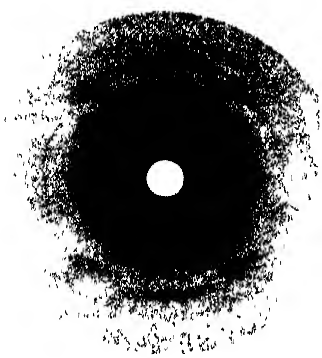


Fig 3*c*

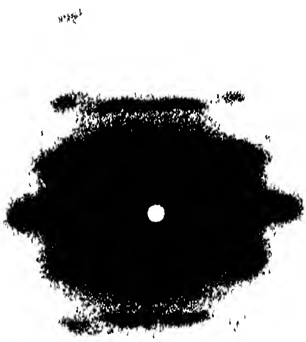
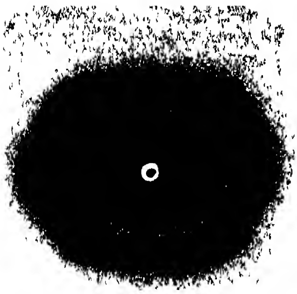


Fig 3*d*

PLATE I



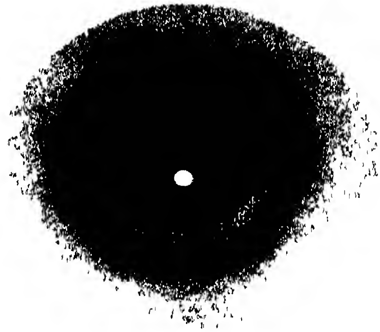


FIG. 5a

FIG. 6a

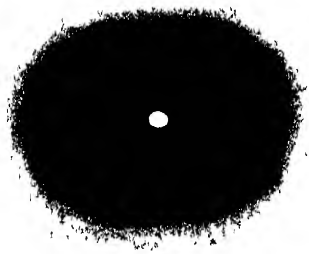


FIG. 5b

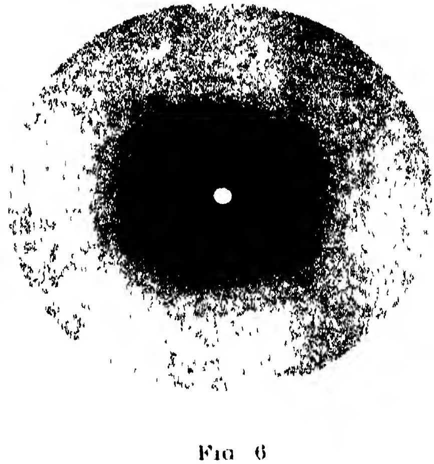


FIG. 6

PLATE II

the "sizes" and modes of combination of atoms that it is possible to predict with some accuracy the dimensions of any molecule

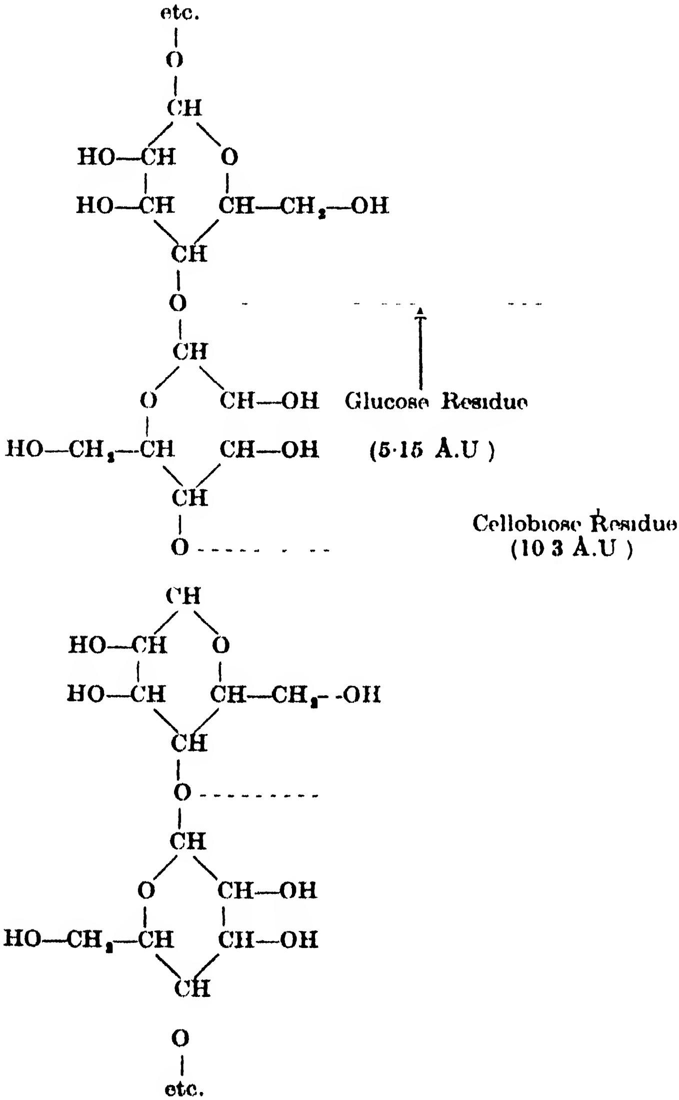


FIG. 4c.

FIG. 4.—Chain-molecules. (c) A short length of the cellulose molecule.

suggested by purely chemical reasoning; and the chemical formulæ as written here, which, it must be emphasised, correspond to the maximum chain-lengths permitted by the various chemical "bonds"

involved, are found to be in excellent agreement with X-ray and crystallographic considerations. Thus, when formerly we wrote down cellulose simply as $(C_6H_{10}O_5)_n$, it transpires now from the interpretation of X-ray fibre photographs in terms of modern sugar chemistry that the formula told only the beginnings of a story of which the next two instalments run briefly as follows. (1) The cellulose molecule is a long chain of glucose residues, some 200 at

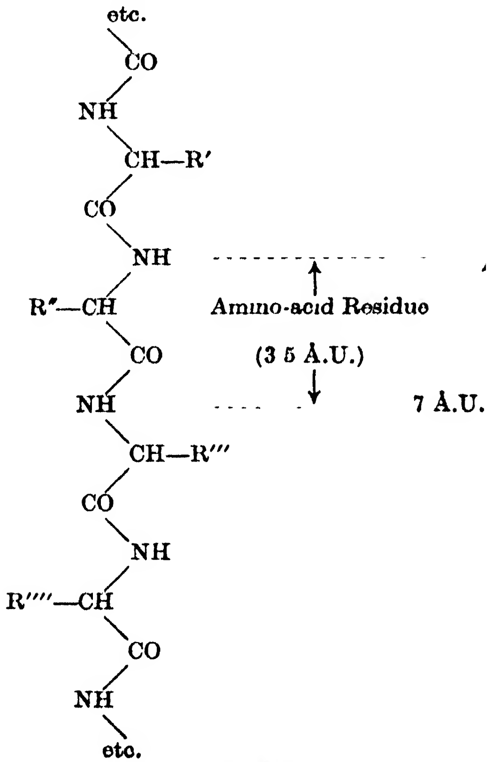


Fig 4d

Fig. 4.—Chain molecules. (*d*) Part of a fully-extended protein chain.

least, linked in 1 : 4 glucosidic linkage and pointing alternately in opposite directions to give an intra-molecular unit (a cellobiose residue) of length 10·3 Å.U. (2) In the solid state cellulose molecules are fully-extended and aggregated into organised chain-bundles with, in ramie for instance, an average of something like a hundred chains per bundle (see Fig. 4*c*).[1] Similarly it has become

[1] The effective cross-sectional area of each molecule is about 33 square Å.U., while the bundles are roughly 50 Å.U. thick and at least ten times as long.

clear that the fibroin of natural silk, for which a few years ago even a rudimentary formula was doubtful, is constructed also of organised bundles of long chains of residues,[1] but this time α-amino-acid residues. About twenty α-amino-acids of general formula

$$\begin{array}{c} \mathrm{H} \\ | \\ \mathrm{NH_2—C—COOH}, \\ | \\ \mathrm{R} \end{array}$$

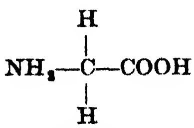
where —R stands for some univalent radicle, constitute in the form of their residues,

$$\begin{array}{c} \mathrm{H} \\ | \\ \mathrm{—NH—C—CO—}, \\ | \\ \mathrm{R} \end{array}$$

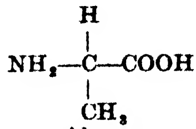
the main components of all proteins, which in turn are probably the fundamental units of all living matter. It was shown by Fischer at the beginning of the present century that the chief mode by which amino-acid residues are incorporated in the molecules of proteins is by way of the "peptide linkage," —CO—NH—, between opposite ends of neighbouring residues, so that the possibility is offered of building an almost endless variety of "polypeptide chains" as illustrated in Fig. 4*d*. R′, R″, R‴, etc., represent the various univalent radicles, which now function as "side-chains" to the main-chain; but the important point to notice is that, whatever the nature of these side-chains, the form and dimensions of the *fully-extended* main-chain should be always very much the same, in fact each residue, in view of X-ray measurements of other carbon chains such as the long-chain paraffins (see Fig. 4*a*), should occupy a length of roughly 3½ Å.U. And this is just what is found from the fibre photograph of fibroin (Fig. 3*d*, Plate I): the chains are built by the repetition—perhaps a hundred times—of an intra-molecular unit 7 Å.U. long, a unit which must consist for the most part of one residue each of the two simplest amino-acids, glycine and alanine,

[1] A "residue" of glucose, $C_6H_{12}O_6$, or of an amino-acid is what is left after the elimination of the elements of one molecule of water. Plants use the carbon dioxide of the air to make glucose for the chain-molecules of cellulose and starch, and animals hydrolyse these back to glucose for their own needs. Similarly they hydrolyse proteins back into their constituent amino-acids, in order to build them up afresh into other proteins.

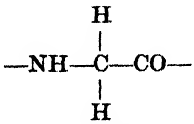
the principal products obtained by the hydrolysis of natural silk, thus :



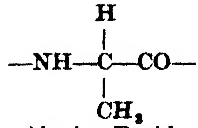
Glycine



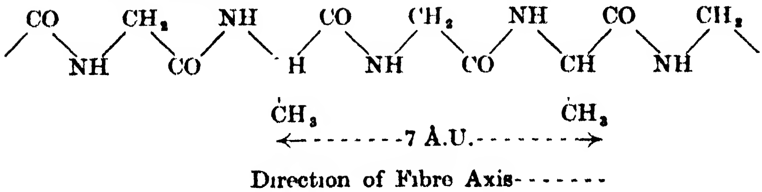
Alanine



Glycine Residue



Alanine Residue



Fibroin Chain

At this stage some surprise might not unreasonably be felt that so much emphasis should be laid on the fact that the molecular chains of both cellulose and fibroin are found in their respective fibres in a fully-extended state ; but there is no occasion for wonder, since nothing short of a knowledge of the actual spatial configuration of molecules suffices for the interpretation of the far-reaching data of modern physics, and the fact just mentioned serves not only to elucidate many of the most fundamental of the properties of the fibres in question, but also, as we shall see below, as the starting-point for a sound stereo-chemistry of the mighty class of proteins in general, with all their beautiful and bewildering manifestations in the structure of living things. Perhaps the most striking deduction—one of considerable technological importance—from the observed form of the cellulose and fibroin molecules concerns the elastic properties of fibres made from them. Such fibres, since the molecules themselves are already fully-extended, should show only a little true elasticity ; they should extend, when stretched, mainly by a process of " molecular drafting," [1] a bodily slipping of the

[1] " Drafting " is the term used in the textile industries for the operation of drawing out, by making the fibres slip over one another, a thick yarn into a longer and thinner one.

chain-bundles over one another in the direction of extension. X-ray examination confirms this view, for their respective photographs—photographs, it will be recalled, of the crystalline chain-bundles—are fundamentally unaltered when fibres of cellulose or silk are stretched. It follows, therefore, that excessive extension of fibres of this kind must lead to a natural "permanent set," an irreversible elongation, as, of course, is well-known in practice.

It is also well-known that wool, together with mammalian hairs in general, does *not* exhibit this property: not only may it be stretched under suitable conditions to extraordinary lengths, but also has it the power of recovering its initial length exactly when released in water. It is plain that wool, though as a protein (keratin) it may be classified with natural silk, is in some way strikingly different in molecular structure from the fibres we have so far discussed. Moreover, the remarkable difference in elastic properties finds its counterpart in the X-ray fibre photograph, which is so unlike that of silk (compare Figs. 3*d* and 3*e*, Plates I and II) as to defy interpretation on the principles outlined above. Substantially the same X-ray photograph is given by all kinds of mammalian hairs, spines, nails, horn, whalebone, etc.; it is the diffraction picture (Fig. 3*e*) of the basic substance of all these epidermal growths, just as Fig. 3*a* is that of cellulose and Fig. 3*d* that of fibroin, from whatever source, respectively.[1]

The problem of interpreting the normal wool or hair photograph is resolved by carrying out the experiment just mentioned for cellulose and silk, that is to say, by stretching the fibres: *it is then found that a new X-ray photograph is obtained*, which reverts to the normal photograph when the fibres are allowed to recover their initial unstretched length. The change from one photograph to the other and back again may be repeated indefinitely, so that it is clear that we are dealing, when we stretch wool or hair, not merely with an internal "drafting" of chain-bundles, but with *a reversible intra-molecular transformation of the fibre substance.* Just as in the case of rubber (see Figs. 2*a* and 2*b*), the reversible intra-molecular transformation of which was discovered by Katz, the hair molecule or complex can exist in two forms, one of which—obviously the longer—can be obtained from the other by the act of stretching. It has been proposed to call these two stereo-isomers, α-keratin and β-keratin. The longer form (β) is unstable under ordinary conditions and contracts almost immediately to the shorter form (α) when the tension

[1] Compare Figs. 3*e* and 5*a*. The quill of a porcupine is in essence only a thick hair.

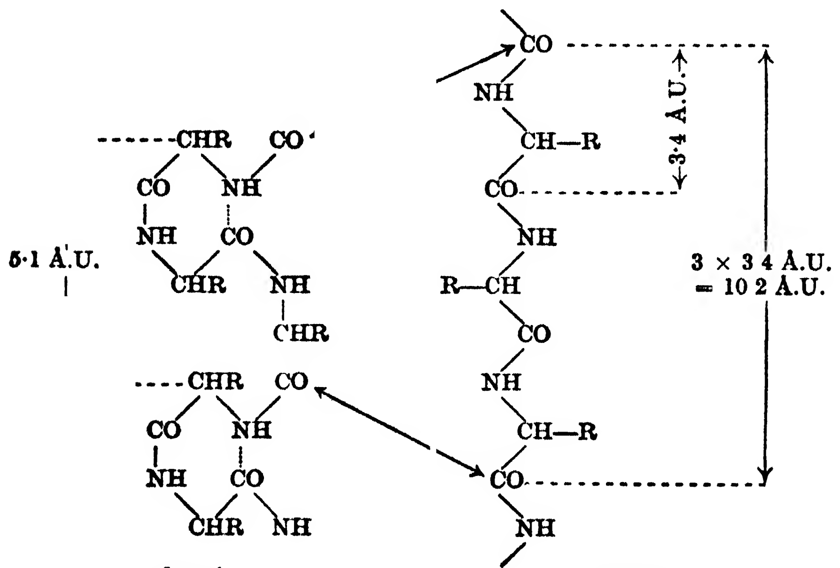
is released in the presence of water. X-ray fibre photographs of the α- and β-keratin of normal and stretched human hair are shown in Figs. *5a* and *5b* (Plate II) respectively: without any expert knowledge of X-ray analysis and crystallography it will be seen at once how unmistakable is the change produced by stretching.

It has been shown above how the X-ray photographs and general properties of silk fibroin can be explained in terms of an inner structure based on fully-extended polypeptide chains of the type shown in Fig. *4d*, in which each amino-acid residue occupies a length parallel to the fibre axis of some 3½ Å.U.; but this simplest of all stereo-chemical interpretations fails entirely in the case of α-keratin as we have just pointed out and, indeed, as we should expect in the light of the profound change in elastic properties as we pass from silk to wool or hair. The trail thus lost is picked up again, however, in the photograph of β-keratin (compare Fig. *5b* with Fig. *3d*), for in it we recognise once more the diffraction characteristics of crystalline bundles of *extended* polypeptide chains, not quite fully-extended, it is true, but so nearly so that each amino-acid residue occupies on the average a length of about 3·4 Å.U. instead of the 3·5 Å.U. found in silk. It now becomes clear what is happening; for *since stretched hair is structurally analogous to natural silk, whether stretched or unstretched, and is therefore built of extended polypeptide chains, unstretched hair must be built of the same chains in a folded state, that is to say, the mechanism of its unusual elasticity is simply that of a molecular spring*; or, in terms of our molecular yarn, we may say that just as the straight fibres of cellulose and silk are spun from straight molecular chains, so hair or wool, naturally "crimped" or wavy fibres, may be thought of as spun from "crimped" molecular chains, the "crimps" of which must always be pulled out before ever molecular "drafting" can occur.[1]

Experiment shows that the maximum reversible extension, in steam or dilute caustic soda solutions for example, of which a uniform wool or hair fibre is capable is always very near to 100 per cent. of its original length: this quantity is, of course, of fundamental significance, and any sound molecular interpretation of hair structure must account for it, at least. We shall not go here into the details of the two X-ray photographs of mammalian hairs, so it may be stated without further delay that these photographs, when considered in

[1] Of course, it must not be inferred from this interesting analogy that the visible crimps of wool or hair are a consequence of the folds in the keratin molecules. The natural waves are produced by some rhythmic mechanism in the follicle out of which a hair grows.

the light of many other facts of a general physico-chemical nature, suggest that the most reasonable stereo-chemical change involved in the stretching of hair is as follows:

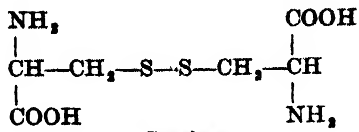


α-keratin *β-keratin*

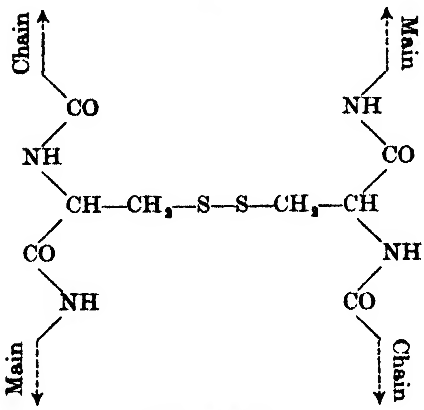
A transformation of this type, from long chains of pseudo-diketo-piperazine rings to the corresponding open chains, is not only in close quantitative agreement with the observed maximum extension, but also offers an explanation of the fact that the intra-molecular pattern in α-keratin repeats at a distance (5·1 Å.U.) which is practically equal to the length of the hexagonal glucose residue of the cellulose molecule (compare Fig. 4*c*). It also accounts, in part, for the great chemical stability of unstretched hairs.

The *orientation* of the hexagonal folds in the molecular chains of α-keratin may be deduced from a comparison with other available X-ray photographs of fibrous proteins, when it is seen that they are formed most probably in planes lying *transverse to the side-chains* (the R-groups, see Fig. *4d*); that is to say, in the transformation depicted symbolically above, the R-groups must be thought of as standing out roughly perpendicular to the plane of the paper, and therefore to the pseudo-diketo-piperazine rings. There seems little doubt that in keratin neighbouring main-chains are linked chemically *via* certain of their side-chains to form a system of " molecular ladders " with strong " rungs," both co-valent and electro-valent. The most

important rung is probably formed by the "double" amino-acid, cystine, thus :

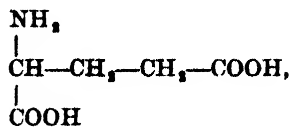


Cystine

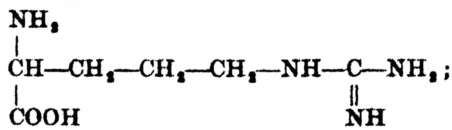


Cystine rung

Another possibility is side-chain linkages of a salt-like character between acidic (electro-negative) side-chains, such as that of glutamic acid,



and basic (electro-positive) side-chains, such as that of arginine,



while still another is the formation of lateral peptide linkages between acidic and basic side-chains. But for our purpose here it is unnecessary to discuss them, the point we wish to make being simply that the keratin complex should be pictured not as a system of parallel but independent polypeptide chains, but rather as a system of molecular ladders held together by a variety of side-chain rungs of undoubted chemical stability. Detailed examination of the X-ray photographs suggests also that all the side-chains lie more or less in

one plane, and that they are confined to this same plane in *both* α- and β-keratin. This means that the keratin crystallites must be composed of polypeptide *sheets*, each sheet being a kind of molecular grid elongated in the direction of main-chains which are themselves linked laterally by a variety of side-chains, while neighbouring sheets are joined simply by the inter-molecular attractions which are the basis of crystallisation and cohesion in general. In β-keratin the polypeptide sheets or grids must be thought of as pulled out flat, but in α-keratin they are buckled, and thereby shortened, by a long series of folds in the main-chains.

It is not difficult now to appreciate the essential difference between the intra-molecular transformation of hair and that of rubber. Stretched rubber is definitely a fibrous product, as all its properties and X-ray photograph show; but the side-linkages between the long straight chains of polymerised isoprene (Fig. 4*b*) which lie parallel to the direction of stretching are of a purely cohesional nature, so that when the chains collapse into the crumpled form (unstretched rubber), the result is merely a "higgledy-piggledy" arrangement, as is shown by the "amorphous" X-ray photograph of Fig. 2*a* (Plate I). When the straight chains of β-keratin (stretched hair) collapse into the crumpled form (unstretched hair), chemical cross-linkages preserve the grid-like sheets; the grids thus contract without causing a general break-up of the structure, with the result that *both* X-ray photographs of hair are of matter in an organised state.

The grid-like structure of keratin provides us also with a satisfying mental picture of the actual molecular forces which are the seat of its contractile power, and helps us to understand for the first time the true nature of the process of "setting" wool or hair in an elongated form. From what has been said above, the "molecule" of keratin comprises at least one of the polypeptide grids just described, and considering the complexity of side-chains—the products of hydrolysis contain some fourteen amino-acids—and the variety of their bonding, it would be quite unreasonable to expect the system to be in equilibrium in just that state in which the relatively simple fibroin is in equilibrium, namely, when the main-chains are fully-extended; and, indeed, it is an experimental fact that the grid settles down into a "position of ease" which is highly contorted! Just as even the simplest molecule has its own specific shape, its configuration of minimum strain and potential energy, so α-keratin is the configuration of minimum strain in the normal keratin complex; and though it can be shown from detailed atomic models that the full extension of 100 per cent. can be carried out

without disrupting the grids, yet it is clear that almost inevitably the operation will produce in the side-chains a multitude of stresses which are the driving force of the observed contraction when the stretched fibre is released. At the moment we are in a position to form only the most general ideas about these complicated stresses, but chief among them it seems probable that we must count (1) stresses in the cystine rungs (cystine is the most abundant amino-acid in wool and hair and is responsible for most of the sulphur found in these fibres); and (2) attractive forces between the electro-positive (basic) side-chains such as those of arginine and lysine and the electro-negative (acidic) side-chains such as those of glutamic and aspartic acids. In fibroin the majority of the "side-chains," $-H$ in the glycine residues and $-CH_3$ in the alanine residues, are comparatively inactive, and the side-to-side cohesion of the long main-chains is sufficient to keep them in the straight form: long-range elasticity is therefore absent in silk.

The "setting" of wool or the "permanent waving" of human hair is a consequence of the hydrolytic attack of steam and other reagents on the strained side-chains of β-keratin. Modification by displacement or actual breakdown occurs—it is revealed directly and with geometrical precision in X-ray photographs such as Fig. 5*b* (Plate II)—in such a way as to relieve the strain and dissipate the tension: the displaced or hydrolysed side-chains thereupon re-combine in or take up new positions of equilibrium, the whole series of changes from breakdown to re-combination depending in a complex manner on the temperature of the setting agent, the extension of the fibre, and the time during which it is exposed to attack. The property of wool and hair of being "set" in the stretched state is thus an effect of side-chain re-arrangement or re-combination leading to new configurations of minimum strain.

The most striking deduction, however, from this line of argument is that *during the interval between side-chain breakdown and re-combination the keratin complex must be in a relatively labile state in which entirely new properties may be looked for; in particular, we may expect enhanced powers of contraction.* This prediction has now been abundantly justified, and it has been proposed to apply the term "super-contraction" to the new power of contraction so developed. A simple way of demonstrating it is to stretch a wool fibre in water to an extension of 50 per cent., say, expose it while held stretched to the action of steam for about two minutes, then remove all restrictions and allow it to contract freely in steam. *It will then be found that it takes up finally a length which is only about two-thirds of its original unstretched length!*

It is somewhat difficult to decide where to close a short article of this kind, for if it has served its purpose, at least it has indicated, not only some of the achievements of the X-ray method in the investigation of biological structures, but also how much has been left unsaid and yet how much remains to be done. The details of what has been left undescribed may be found elsewhere (see references below), while for the rest we must look to the future. The promise, however, appears immense. We are only just at the beginning of the X-ray study of the products of vital activity, but already as we proceed further and further in the direction we are at present travelling, it seems more and more certain that we are really penetrating into the secrets of the mechanism of life itself. One more illustration of the method of advance is perhaps worth mentioning here, and that is a recent X-ray examination of the structure of the cell-wall of the alga *Valonia ventricosa*. This alga grows in warm seas in the form of cellulose balloons, as much as an inch in diameter, which are single biological cells lined with a protoplasmic layer and containing fluids involved in the process of growth. Fig. 6*a* (Plate II) shows a single cell mounted on the end of a glass capillary tube, after being emptied, washed, re-inflated and dried for X-ray examination; while Fig. 6*b* shows the appearance of the outer surface of the wall as viewed at a high magnification under the microscope.[1] Fig. 6*c* is an X-ray photograph of a small area of the wall: its peculiarity lies in the fact that it consists actually of *two* X-ray photographs, each similar to that of ramie shown in Fig. 3*a* (Plate I), and crossed at an angle rather less than a right angle. It follows directly from this observation that the cell-wall of *Valonia ventricosa* is a kind of cellulose "fabric": whereas ramie is built out of only one set of cellulose chains forming a steep spiral round the fibre axis, the wall of this balloon-like alga has been woven by Nature out of two sets of crossed cellulose chains, very much as we should construct a fabric balloon from visible threads. Furthermore, the origin of the crossed striations seen under the microscope is also revealed. For many years the significance of these striations had remained a mystery, but now it appears that they are simply the "grain" of the ultimate cellulose framework: comparison of photomicrographs with the corresponding X-ray photographs shows at once that the striæ are parallel to the two sets of cellulose chains.

Figs. 6, *a*, *b*, and *c* (Plate II), serve admirably to illustrate the advance of knowledge into the inner structure of things. First we have the object as seen by the naked eye, then as viewed with

[1] For these two photographs I am indebted to Dr. R. D. Preston.

the utmost resources of visible light, and finally as it appears in the "light" of the X-rays. Each aspect reveals finer and finer details, each fresh interpretation betrays some more closely-guarded secret, each step brings us closer and closer to the heart of—what ?

REFERENCES

K. H. Meyer and H. Mark, *Der Aufbau der hochpolymeren organischen Naturstoffe* (Leipzig, 1930).

W. T. Astbury, *Fundamentals of Fibre Structure* (Oxford, 1933).

"The Colloid Aspects of Textile Materials and Related Topics" (a General Discussion held by the Faraday Society, September 1932). *Trans. Faraday Soc.*, **29**, 1933.

W. T. Astbury, T. C. Marwick and J. D. Bernal, "X-ray Analysis of the Structure of the Wall of *Valonia ventricosa*.—I." *Proc. Roy. Soc.*, B, **109**, 443, 1932.

W. T. Astbury and H. J. Woods, *X-ray Studies of the Structure of Hair, Wool, and Related Fibres.*—II. *The Molecular Structure and Elastic Properties of Hair Keratin.* (Royal Society—in press.)

SOME ASPECTS OF THE CHEMISTRY OF THE PLANT CELL-WALL[1]

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PREAMBLE

WITH the advances in knowledge, and the accumulation of observations and facts that have marked the scientific work of this century, there has been a spreading of a myopic condition amongst many of us scientific workers, a shortsightedness which is not infrequently accompanied by a narrowness of mind. In increasing specialisation, and the burning desire to know more and more about less and less, we often fail to appreciate the importance in our own work of the results and methods of attack of other investigators with a different view-point. Though the barriers between so-called subject and subject have been falling fast, there is still often a narrowness of vision, caused perhaps by staring too hard and too long at the goal which we think is ours.

In the wide problem of the nature of the cell-wall of plants there is a rather good example of this unfortunate outlook. Because of the complexity of its composition, its variation in different tissues, and above all the many different economic uses of some of its constituents, intensive work has gone forward for many years, and yet the gaps in our knowledge and understanding of the precise nature and of the rôle and method of formation of even the major components are still enormous and distressing. These gaps are due largely to this myopic outlook, and to our smug satisfaction that the ultimate success will be in our own personal field of work.

Workers in many fields are interested in the cell-walls of plants. The cytologist is mainly concerned with the life history and functional changes of the cells—to him the walls are merely partitions which partially separate the protoplasm of one cell from that of its neighbours and provide him with the unit for work. The histo-

[1] Based on a lecture given before the Wisconsin chapter of Sigma Xi, University of Wisconsin, U.S.A.

logist is interested in the cell-wall as it affects the anatomy and functional changes of the tissue, and he expresses it largely in terms of substances which stain in a particular way and are extractable by certain reagents. The plant physiologist regards the cell-wall largely from a physical point of view, since it is the interface at which certain cell products accumulate and through which nutrients and elaborated products must pass. The chemist is in general interested only in the mature cell-wall and then often only in a particular constituent as an organic entity—its molecular constitution and its economic uses. To him the other components of the wall are often merely nuisances which are difficult to remove.

With these mutually divergent views, how is it best to approach the subject? Were it possible to do so it would be best treated by outlining the chemical history of the cell-wall from extreme youth, through adolescence, maturity and senescence, to death and the post-mortem changes, relating the particular changes and modifications to the functional differences and the metabolic drift of cell activities. That is the ideal, the peak to be surmounted. The chemists will not achieve it without the plant physiologists, who must advance first our knowledge of plant metabolism, the histologists must provide the link between form and function, the cytologists the inherent mechanism and basis of functional differentiation. This preamble is a plea for a better planning of the attack, and for a sympathetic assistance and co-operation among workers in different fields, rather than a mutual lack of interest or a scornful intolerance.

From a chemical point of view the methods of attack are fundamentally two, but these are by no means independent, though often regarded as such. These are the micro-chemical (in the botanical sense) and the macro-analytical procedures. Separately, both have their shortcomings; the former, though it may reveal the distribution of substances with certain staining properties and particular solubilities, throws little light on the ultimate constitution of these substances; the latter, though it may do that, fails in general to indicate the method of linkage with, or relationship to, other cell-wall components, largely owing to the drastic means which it is usually necessary to employ for extraction, purification, and recognition. The advocates of the macro-analytical method, that is to say, the ordinary plant chemists, are in general over-confident that the ultimate victory will be to their bludgeon. Those upholding the micro-chemical methods are often misled by their results. Their evidence is too frequently the result of staining observations not rigidly characteristic, since the effects on specific

staining reactions of association of one substance with another have been insufficiently explored.

THE BIOGRAPHY OF A CELL-WALL

Before proceeding to a detailed treatment of certain structural substances and their rôle in the mature cell-wall, it might be well briefly to review the changes that the wall of an abstract plant cell will undergo during its life. It is impossible to be very definite since the type of plant and functional differentiation of the tissue profoundly affect the wall, but nevertheless certain general modifications are observable.

Practically all the recent chemical work that has been carried out on the cell-wall of the very young cell is due to J. H. Priestley who, working with the meristematic tissue of *Vicia faba* employed a combination of micro-chemical and macro-analytical methods. While the work was apparently carried out with great care, there are one or two points to which exception may be taken, the chief being the deduction of certain linkages between constituents, from staining and solubility evidence alone. Mechanical and physical causes may provide the explanation for the reactions observed, and caution should be exercised in the allocation of chemical explanations to what may be physical phenomena.

The primary cell-wall in division is relatively inconspicuous and of unknown composition. It is apparently homogeneous physically and often stains with protoplasmic dyes. In all probability it is extremely complex, since at the interfaces of actively developing cytoplasm, protoplasmic constituents, largely proteins, lipoids, etc., might be expected to be present. Its subsequent history represents a progressive simplification in composition, with an increasing complexity of organisation. With advancing age and slackening of growth, the metabolic activities of the cytoplasm undergo change; the cytoplasm becomes less concerned with growth and more concerned with carbohydrate transformations. Cellulose may be demonstrated in the walls at an early stage if certain extractions are first carried out. It appears rapidly at the protoplast surface and in spite of cell extension the walls get thicker. Priestley assumes the cellulose in the root meristem, at this stage, to be in combination with fatty acids and with protein; while in the shoot, cellulose and pectin preponderate. The pectin he states also to be linked chemically to the cellulose. As the tissues become older he suggests that there is a disappearance of protein from the wall, which remains largely cellulosic but containing in chemical combination some fatty acid and pectin. There

may also be free pectin in the wall at this period. The middle lamella, or intercellular matrix, which appears to originate on the surfaces of the plasma membranes after division, is stated by Priestley to be a pectin-protein complex, firmly linked but resolvable by enzymes or alkali. With increasing age, the protein apparently disappears, and the middle lamella then seems to be composed only of calcium pectate. The later changes are more difficult to describe, since the functional adaptations of cells influence so markedly the character of the walls. Polysaccharides continue to be deposited at the cell-wall, at first mainly cellulose and pectin, but later hemicelluloses appear in increasing quantities. The process known as lignification sets in sooner or later, depending on the tissue, and consists in the further deposition of encrusting substances, the chief of which, of course, is lignin. Lignification is usually accompanied by definite changes in the form of the cell. It may be only partial or complete. In woods it is in general accompanied by the death and disappearance of the protoplasm, though this is not necessarily the case. Pectin seems almost completely to disappear in the lignification process, and in woods, where it has gone to an extreme, only traces, if any, of the pectic substances are found. Even the middle lamella undergoes modification, and the calcium pectate of maturity gives place to the lignin of senescence. Indeed, it seems that a fairly large percentage of the total lignin, perhaps as much as half, is in the middle lamella, which indeed may even show traces of structural form This replacement in the lamella must be of considerable importance in providing extra rigidity and mechanical strength of the tissue. Perhaps there is tendency sometimes to over-emphasise the lignification process as a senescent change, since quite young cereal plants often contain very appreciable amounts of lignin.

The Building Stones

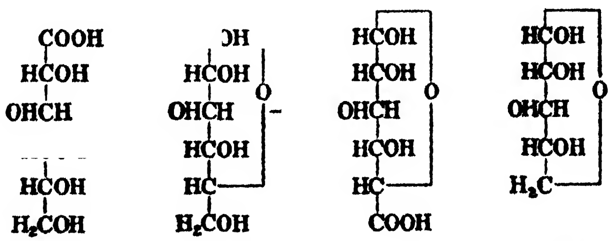
In this brief thumb-nail sketch no attention has been paid to the non-structural constituents of the wall, of which there are many. Tannins, gums, cutin, suberin, resins, and other extractives may also appear there, but can hardly be regarded as skeletal substances. The major structural constituents are cellulose, the associated polysaccharides, the hemicelluloses, and lignin, with the pectic substances offering certain interesting points. Therefore we see that while the cytoplasm is essentially nitrogenous, the fundamental building material of the mature cell-wall is carbohydrate in nature, and the building stones certain monosaccharide sugars. Some hexose sugar, the exact nature of which is still

controversial (though the glucose adherents appear to be winning the day), is formed as the major photosynthetic product, and by epimeric change, condensations, and oxidations, a whole range of polysaccharides and related compounds are formed. Two properties of sugars stand out as of great importance when considering the formation of the cell-wall constituents. The first is the ready mutability and highly labile nature of the free hexose sugars, and the second is their ability to undergo condensation and polymerisation into polysaccharides of great stability. Of the sixteen possible aldohexoses only three occur in nature, d-glucose, d-mannose, and d-galactose, indicating a very selective conversion from the photosynthetic sugar. While the interconversion of d-glucose and mannose is a change which can easily be accomplished, that from glucose to galactose has never been achieved *in vitro*. But it is clear that it is one which must take place in both animals and plants with extreme ease.

The ability of sugars to undergo condensation to polysaccharides is remarkable. Hexose units can apparently link together in such a way as to form huge molecules of unknown molecular weight. To what extent the natural aggregate is an exceedingly long chain, or what part polymerisation or residual valency forces play, remains in most cases obscure. Hydrolytic studies make it probable that in general the polysaccharides are large molecules, and not di- or tri-hexose anhydrides polymerised by the interplay of residual valencies, since, if only such forces have to be overcome, it is difficult to see why such drastic methods as are often necessary should have to be employed.

Though these remarks were made directly on the hexose or six-carbon atom sugars, they apply with equal force to the five. The origin and formation of the pentoses in the plant is still quite obscure. The amount of free monosaccharide pentose in plant tissues is in general quite small, but they occur widely in condensed molecules as pentosans, and in the conjugated polysaccharides of the type of the hemicelluloses and pectic substances. Some workers have affirmed that pentoses are formed as oxidation products of hexoses, and that they are relatively inert and of the nature of waste products. Though they may conceivably be inert as far as the regular cycle of cell metabolic changes is concerned, nevertheless it is difficult to believe that they are waste products, since they appear in so important a constituent of the protoplasm as the nucleoproteins, and also in pectin which, as we shall see, is a cell-wall substance produced very early, when the cell is actively growing. If we are unwilling to assume that pentoses are a direct

photosynthetic product, and there is no evidence to substantiate such a view, how then are they formed? The clue to their probable method of formation is, however, provided by the widespread occurrence in plant tissues of a certain type of sugar known as a uronic acid. In aldose sugars the α-carbon atom (the potentially aldehydic group) is the reactive point and sugar reactions are largely due to this group. If it were oxidised an acid would be formed which in the case of glucose would be a gluconic acid. In polysaccharides and glucosides, this aldehydic group is shielded from attack by linkage, and mild oxidation converts the terminal carbinol group to carboxyl acid giving an aldehyde acid which is known as uronic acid. Decarboxylation of this acid would then



Gluconic Acid. Glucose. Glucuronic Acid. Xylose.

result in the formation of a pentose. It is certainly significant that in nature glucose and xylose, and galactose and arabinose are frequently found in combination and these sugars are the natural partners if the formation of pentose takes place along these lines. The whole question of the position of the uronic acids and the pentoses in the metabolism of the plant and the fabric of the cell-wall is a very fascinating one and a fruitful field for investigation.

In solving the problem of the inter-relationship of the cell-wall constituents, the essential prerequisite is a full knowledge of the reactions of the carbohydrates. Polysaccharides are not easy subjects for investigation; they yield few derivatives and are not readily substituted. The general line of attack is to examine the hydrolytic fragments after violently breaking the molecule, but this throws very little light on the nature of the linkages involved or on the size of the aggregate.

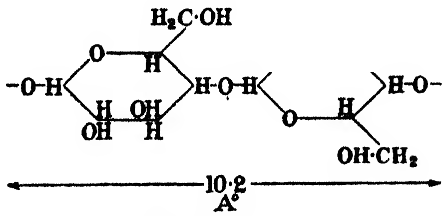
Cellulose

The most important polysaccharide to be considered is, of course, cellulose, but there is no need to loiter very long on this subject. Its economic uses and the industrial applications of its

derivatives have resulted in an enormous volume of research on every phase and facet. From a constitutional point of view it has especially been the battlefield of the carbohydrate chemist. Because lignin and polysaccharides of hemicellulose nature are so intimately associated with the cellulose that real separation is an exceedingly difficult matter, many have insisted that several chemically different celluloses exist. Indeed, Cross and Bevan in their pioneer work defined cellulose generically as "all non-nitrogenous structural material of the wall" and postulated a number of compound celluloses, as, for example, lignocellulose, pectocellulose, mannocellulose, adipocellulose, cutocellulose—to some of which they were even courageous enough to assign formulæ. Of recent years this view had met with great opposition, and the evidence available points to the fact that carefully purified wood celluloses, flax cellulose, or straw cellulose, contain a fraction which, though different in mechanical arrangement, is identical chemically with the very pure cellulose of the cotton plant. The main attack on the problem has lain with the carbohydrate chemists and has depended on the constitution of glucose, which is now generally accepted as containing in its normal form a 1 : 5 oxidic bridge, or amylene oxide ring.

The presence of this form of glucose as the ultimate unit of the cellulose molecule has been demonstrated unquestionably by acetolysis and methylation, which also show that carbon atoms 1 and 4 are involved in the polysaccharide linkage. A disaccharide cellobiose may be obtained on hydrolysis and has been shown to be composed of two such glucose residues linked through the 1 and 4 carbon atoms. Recently Willstatter and Zeichmeister have isolated several crystalline intermediates between cellulose and glucose consisting of three and four glucose units, that is a cellotriose and a cellotetrose. But by chemical means it was not possible to go much further, and the next step was due to the application of X-ray analysis to cellulose fibres, in which field Sponsler of California was the pioneer. The conclusion of this work, which has been greatly developed by Meyer and Mark and others in Germany, was that the cellulose fibre, since it gave a diffraction pattern contains crystals or crystallites, which are oriented more or less in one direction. Further, that in each crystallite there is a unit which is repeated in this direction. The length of this unit, or the "identity period" of the substance, was found to be 10·2 Å, which is, in fact, the calculated length of the two glucose groups linked together in cellobiose. The inference therefore is that the cellulose molecule consists of a chain of unknown length,

the links of which are cellobiose units joined by primary valencies. The length of the chains is not certain, but there is some evidence that they are at least 600 Å, which would imply 50–60 cellobiose groups as a minimum. Indeed, the work of Staudinger on viscosity can only be satisfactorily accounted for by a much higher figure. The optical evidence goes further, however, and indicates that



Cellobiose Unit.

these chains are grouped together in bundles, known as micellæ, being held by the secondary valency attraction of the oxygen atoms. These cellulose micellæ are, therefore, stabilised longitudinally by primary valency forces, and laterally by secondary valency forces. The significance of such molecular orientation in the architecture of the cell-wall is an intensely interesting subject for speculation, and one to which reference will be made later.

Hemicelluloses

The non-cellulosic polysaccharides of the cell-wall are an ill-defined group of substances, not easy to isolate and quite difficult to purify and characterise. They are generally known as hemicelluloses—a term originating many years ago with Schultze, who based his differentiation between the celluloses and the hemicelluloses mainly on the ease of hydrolysis of the latter by acid. The celluloses, he stated, required concentrated acids and yielded chiefly glucose, while the hemicelluloses in most cases gave rise to other sugars, such as mannose, galactose, arabinose, and xylose. He found that the hemicelluloses were usually soluble in dilute alkali in which true cellulose was insoluble, and employed an alkaline extraction in the preparation of such substances from a wide range of plant materials. He believed that a close relationship existed between the two groups and that hemicelluloses might be an intermediate stage in the development of the latter. These relationships were, of course, purely speculative. The definition to which it is convenient to work at present, is to describe as hemicelluloses those polysaccharides which are insoluble in water, or soluble only with difficulty, which are readily soluble in dilute alkali, and

hydrolysable by hot dilute acids to give hexoses, or pentoses, or a mixture of these with uronic acids. The name hemicellulose is unfortunate and misleading in its reference to cellulose, but until more is known of their structure and properties it would be unwise to suggest any alternative or any classification. The late Professor Schryver proposed the term "polyuronides" for such members of this group as contain uronic acids, and there is a good deal to be said for a differentiation between those containing uronic acids and those in which they are absent. The literature contains a number of references to polysaccharides possessing the properties of hemicelluloses but yielding on hydrolysis one sugar only. Many of these substances require re-investigation, since in a number of cases small quantities of other sugars or uronic acids have been shown to be present. In considering the function or rôle of the hemicelluloses, while it is true that the majority are just encrusting substances and are very generally polyuronide in nature, there are some which are undoubtedly reserves, more especially in the germination of seeds. Certain workers have stated that in woods there is some seasonal change in the hemicellulose content of the cell-wall and that these play some part in the renewal of growth in the spring. The evidence is, however, entirely inconclusive, being based in most cases solely on the total pentose content of the wood, a method which cannot be considered to give any reliable index of the amount of heterogeneous polysaccharide present. Of the type of linkage present in this class of substance, practically nothing is known. They are non-reducing, so that carbon atom 1 must be involved, and they are hydrolysed fairly readily by dilute acids— 3 per cent. sulphuric acid for 3–5 hours is usually sufficient to effect complete hydrolysis, though considerable variation is observed. If uronic acids are present, the estimation of reducing power is not an exact measure of the progress of hydrolysis owing to the instability of these substances to dilute acids. There is no evidence for any organisation or orderly arrangement of the constituent units; mild hydrolysis does not seem, as in the case of certain gums, to remove progressively a particular unit and to indicate some more resistant nucleus. Instead it appears to be all or nothing, either hemicellulose or sugars. On general grounds one might presuppose a 1 : 4 anhydro-linkage, but this fails to take into account the relative ease of hydrolysis of the hemicelluloses as opposed to the stability of cellulose. It may be that the hemicelluloses are constructed not of the normal type of sugar but of the more reactive γ-sugars with a 1 : 4 or butylene oxide bridge, or contain some units of this type, though it must be admitted

that there is no evidence for such an assumption. The whole field of the constitution of the hemicelluloses is a fascinating one and relatively untouched. The few workers who have approached the problem have been able only to get some idea of the constituent groups, and have been unable to form any picture of the way in which they are conjugated. The difficulties are enhanced by the fact that the physical properties of these substances are so much alike that it is impossible ever to be sure that a preparation is a single entity, or just a mixture of several hemicelluloses. Nevertheless, in the formation of this class of substance probably lies the key to the carbohydrate changes in the cell.

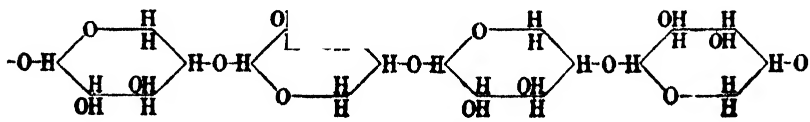
Cellulosans (Polysaccharides associated with Cellulose)

There is, however, another type of polysaccharide found in the cell-wall in much more intimate association with the cellulose than the encrusting hemicelluloses appear to be. If a plant material such as straw or wood be taken and the encrusting substances, mainly hemicellulose sand lignin, be removed by one of the well-known methods, the residue is largely cellulose, but almost invariably contains also a certain amount of pentosan or hexosan which may be removed only by very drastic means. The cellulosic product obtained by the chlorination method of Cross and Bevan usually contains this fraction. In the case of cereal straws, esparto grass, and certain woods, this associated polysaccharide appears to be a xylan. The chlorinated residue from oat straw, for example, contains about 17 per cent. xylan, and that of esparto pulp about 18·5 per cent. The cellulose of many woods, particularly among the gymnosperms, contains not xylan but mannan. It has been stated that mannan probably occurs in all the gymnosperms—an interesting observation since it is apparently unusual in the hardwoods, except in a few cases in the encrusting hemicelluloses. Haworth and Hirst have carried out an elaborate investigation of the nature of the xylan in esparto cellulose, and have obtained unquestionable evidence that the linkage in the xylan molecule is of the 1 : 4 type and that the xylose units have the normal amylene oxide bridge. This is an extremely important observation, since it will readily be seen that the xylan unit differs from the cellulose unit only in that the terminal carbinol group is missing. The units of the xylan molecule are of the same size and occupy the same space longitudinally as the glucose units in cellulose. Indirectly X-ray analysis gives additional evidence for the steric similarity in size and arrangement of the xylan molecule, since radiographs of purified fibres with widely different xylan contents,

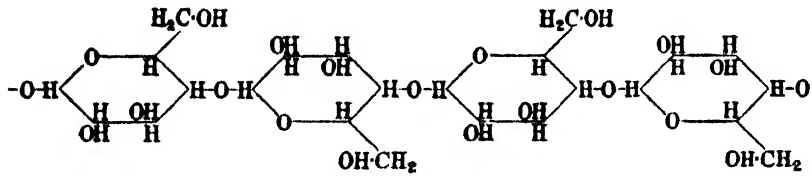
as for example, ramie, flax, esparto, and cotton, give evidence of the same arrangement, and show no trace of any material with an identity period different from that of glucose. This steric similarity together with the extreme resistance of the xylan to extraction, makes it likely that it is laid down during growth in the closest physical association with the cellulose and probably by the same mechanism.

The mannan, seemingly characteristic of the gymnosperms, has not been investigated in the same way, but it seems probable by analogy that it too will be found to be a 1 . 4 anhydro-mannose, and therefore sterically similar in size to cellulose and xylan, but differing from the latter in containing the terminal carbinol group as a side chain.

This association of cellulose and xylan has caused some workers, notably Meyer, to explain the formation of xylan by oxidation



Xylan



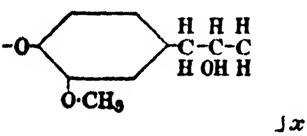
Cellulose

from cellulose, the terminal carbinol groups of the glucose units first being converted to carboxyl to give a long chain polyglucuronic acid, while on decarboxylation would give xylan. This theory for several reasons does not appear very feasible. The very fact of orientation of the cellulose molecules and their aggregation into micellæ makes it unlikely that they would undergo a reaction of this sort. Further in the type of oxidation that one would expect in a plant the change would be progressive rather than sudden, and uronic acids should be present in a detectable amount. Only the merest traces of uronic acids have been found in isolated celluloses and these appear to be due to the carboxyl groups of oxycellulose. Moreover, any change of this sort would result in the mechanical weakening of the cell-wall. An additional point is that in cereal straws at least, xylan appears associated with the cellulose at an extremely early stage, though it is true that cellulose

layers deposited later contain a higher percentage of this substance. For these reasons, it is more probable that the cellulose and xylan are laid down in association at the same time by the same mechanism, the xylan participating in the micellæ just as the cellulose molecules do. Because of the absence of a projecting carbinol group the secondary valency forces holding the xylan to the cellulose chain are likely to be less, and the xylan is therefore extractable with difficulty. In parenthesis, this case of cellulose and the associated xylan is an excellent example of the difference in properties produced by a small difference in constitution and it is clear that when considering the reactions of cellulose, more attention should be paid to the sixth carbon atom

Lignin

The other major cell-wall constituent is lignin, the study of which is made very difficult by its inert character. The violent means which must be employed to separate it from cellulose probably profoundly modify its character. Different methods yield different products and no agreement exists as to the best method of preparation. Many formulæ have been proposed, to most of which objections can be found. The general conclusion is that lignin contains condensed unsaturated aromatic nuclei, perhaps with an aldehyde or ketone group, and is substituted by hydroxyl, methoxyl, and possibly acetyl groups. It does not appear to be



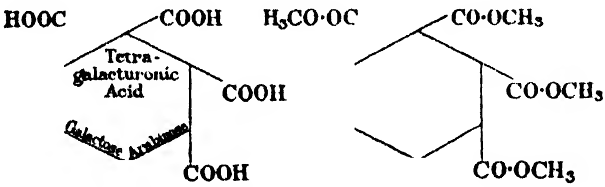
Lignin.
(Freudenberg.)

uniform from plant to plant—there is a wide variation in the methoxyl and acetyl contents of lignin from various species of woods, and variation is even reported to exist in different parts of the same tree. Ritter has found that the lignin of the middle lamella differs considerably from that of the cell-wall in methoxyl content, and is appreciably more soluble in 95 per cent. alcohol. As an example of suggested basal formulæ for lignin, the most recent, given by Freudenberg might be quoted. There does not seem to be anything more to recommend it than many of the others except perhaps its simplicity. The lignin of plants and woods he supposes to be a polymerised and substituted continuous ether of

the type indicated. There is some evidence of relationship between lignins, certain resins, and the phenolic residues of tannins. The whole question of the formation of aromatic nuclei in nature is a very obscure one. The assumption is that they are not a direct photosynthetic product, and must, therefore, be formed from carbohydrate groupings, possibly in some obscure way from the pyran or furan rings of sugars It is perhaps significant that furan, benzo-furan, and pyran structures have all been stated by various workers to be present in the lignin complex.

PECTIN

Another cell-wall constituent, quantitatively less important than the "big four," but of very considerable interest, is pectin, or rather, the pectic substances, which in the young cell-wall and in that of fruits and roots must be given pride of place Our knowledge of this group is rather more satisfactory, since they can be extracted readily by quite mild treatment The key member of the group is pectic acid, from which the others are derived It is unlikely that pectic acid as such exists in the plant, though its calcium salt appears to be the chief constituent of the middle lamella, and to be present also in cell-walls. Pectic acid is largely composed of galacturonic acid, to four molecules of which are linked, according to one formula, one molecule each of galactose



Pectic Acid. Pectin.

and arabinose, the whole making a closed six-membered ring Such a formula is in agreement with the values obtained for pentose, uronic acid, and calcium content of the pectic acid prepared from many sources. Derived from pectic acid, by simple methoxylation of the carboxyl groups, is the substance known as pectin, or soluble pectin. The ester groups may very readily be split off by treatment with dilute alkali in the cold. It is this substance which constitutes a great part of the pectin in the cell-wall and which is present also in the cell-sap.

Much of the fundamental work on the pectic substances is due to Felix Ehrlich, who originally described the existence of tetragalacturonic acid in the pectin molecule. Ehrlich does not accept

the six-membered ring formula, nor indeed the uniformity of pectin preparations from different sources, and prefers to regard the pectin molecule as consisting of a closed tetra-galacturonic acid ring, to which is attached sugars and acetyl and methoxyl groups, the precise position of attachment not having been determined. These views are contrary to the findings of the majority of workers, but nevertheless the fact remains that Ehrlich is probably the most responsible investigator in this field His work is open to criticism chiefly as to the method by which he obtains his pectin preparations, one which is more violent than that generally employed.

The third type of cell-wall pectic substance is known as protopectin or pectose, and is insoluble in water. It may, however, be extracted by treatment with hot dilute acid Much controversy exists as to the condition of this form in the cell-wall. It is usually stated to be in combination with cellulose, but the evidence for such a view is very scanty and unconvincing. An alternative suggestion is that this form is a polymerised aggregate in association with iron and calcium.

Whatever the exact formula for pectin may turn out to be, the fact remains that universally distributed in the unlignified cell-wall there are tetra-galacturonic acid, galactose and arabinose conjugated together. The pectic substances, strangely enough, appear to be relatively unstable—the linkages are readily ruptured both by acid and by alkali. No information exists as to the genesis of pectin and little as to its breakdown or ultimate degradation products. The formation of pectin in the plant appears to take place when metabolism is at its highest peak, that is, when growth is most rapid. As growth slows and maturity is reached so does the production of pectin decrease, and that present is slowly converted into other substances. The close generic relationship between pectin and the hemicelluloses has been recognised by a number of workers. Ehrlich has suggested that in the process of lignification, pectin is converted to lignin with the hemicelluloses as a transition product, since it has been observed that unlignified tissues contain relatively large quantities of pectin and small amounts of hemicelluloses, while in lignified tissues there are only traces (if any) of pectin but considerable quantities of lignin and hemicelluloses. While it must be admitted that it makes an attractive theory to couple together pectin and lignin in this way, nevertheless on purely chemical and constitutional grounds it is not easy to see how the transformation may take place, and further the actual amount of lignin present in lignified tissue is very considerably in excess of the amount of pectin which was present in

the same tissue before lignification. On purely chemical grounds it is possible to account for the formation of substances of the nature of pectin and the hemicelluloses by the protracted mild oxidation of linked hexose units. A glucosan on mild oxidation would give rise first to a polyglucuronic acid and this on decarboxylation (itself an oxidative process) to a xylan , a galactan similarly would give an araban via polygalacturonic acid. If the oxidation was only partial, that is to say if some of the hexose units were incompletely oxidised, then complex substances containing hexose, uronic and pentose groups would be given, akin in all respects to the hemicelluloses. It is undoubtedly a fact that it is the derivatives of galactose, possibly formed in this way, that are met with most frequently in this class of substance. Xylans and gluco-xylans seem relatively less common than galacto-arabans. It is curious that galactose thus appears to occupy a place rather more important in this transition to pentosans than does glucose, while it is glucose which is the most widespread unit of plant hexosans. It would seem that the first apparent stage in the oxidation of galactans is the production of pectin, and having regard to the flexibility of the process of mild oxidation, it is perhaps remarkable that a substance of such definite character as pectin should appear. It seems likely that the hemicelluloses are not substances definite in composition, in the way that starch or cellulose may be said to be definite in composition, but are formed on a general plan as the intermediate oxidation products of hexosans. The position of lignin in the cycle of metabolic changes in the cell-wall must remain an enigma till its constitution has been determined. There is no sure evidence as yet that it is a uniform and homogeneous entity.

Cell Structure

So far we have been considering the structural cell-wall constituents as individuals and neglecting the manner of their association one with another. Cellulose is the fundamental molecular combination in the plant world, and " pre-eminently the molecule of growth," a molecule " by the aid of which purpose and direction can be worked out " Direction cannot be obtained without regularity of arrangement—the significance of the molecular orientation of the cellulose units in the architecture of the cell and the tissue cannot be over-stressed. Whether or not all natural cellulose is oriented is not yet clear—it seems improbable—but the fact remains that the major part is so and it is this property which confers on plant tissues longitudinal strength. It seems that the cell-wall is composed of cellulose micellæ packed together

with some sort of organised arrangement. In such fibres as ramie, which have a cylindrical structure, the micellæ are arranged parallel to one another in concentric shells, while in the case of cotton they have a screw-structure. In general, the single micellæ of fibres are oriented not quite parallel to the axis of the fibre, but somewhat obliquely. Such a micellar arrangement is in agreement with the swelling phenomena observed with water or alkali. Fibres show little swelling in a longitudinal direction since the linkages are primary valency ones. But swelling in a lateral direction is considerable since only secondary valencies are involved. The liquids penetrate the gaps between the single crystallites and become adsorbed on the oxygen atoms, which process tends to increase the distance between the parallel chains of glucose molecules Such a concept affects profoundly the theory of chemical combination between cellulose and other cell-wall constituents. Many workers still hold that there is a pecto-cellulose, and a ligno-cellulose, and indeed on purely chemical grounds the case for the existence of the latter is a strong one, unless one postulates for lignin a structure wholly inert and one which can only be rendered soluble by violent chemical means. But while the replacement of any of the side hydroxyls in cellulose would not in any way affect the strength of the chain longitudinally, the increased separation of the chains by the substitution of large groups for the hydroxyls would weaken and destroy the fibrous structure. Such large groups as pectin or lignin would so far separate the longitudinal chains as to remove all possibility of lateral adhesion. Nitrocellulose retains its fibrous structure better than the acetate, since in the latter wider separation is required and the lateral integrity jeopardised. On theoretical grounds therefore it is very difficult to see how oriented cellulose could participate in general chemical linkage with other large molecules.

Apart from the micellar units, some evidence has been obtained for the existence of larger component elements in the cell-wall also showing orientation, according to the structure of the tissue. Ritter has isolated from the cell-wall of certain woods, small fibrils, themselves resolvable into minute fusiform bodies. These fibrils were oriented some at 90° to the long axis of the wood, and others obliquely at 30–45°. The fusiform bodies overlapped one another and appeared to be cemented together, possibly by lignin. The problem of the distribution of lignin and the other encrusting substances and their relation to the cellulose micellæ remains yet to be solved. Neither the theories of absorption nor of combination are sufficient in the light of this recent work on the molecular

anatomy of cellulose, and we must await the results of some new line of attack.

Some day, perhaps, the cycle of changes resulting in the formation of the cell-wall will be known, and its structure and organisation made plain That will probably not be until the metabolic activities of the plant cell are fully understood. At present we can but see through a glass darkly. When we see it clearly, we shall find that the finished picture is a tapestry in whose weaving biologists and chemists in many different specialised fields will have had a hand.

CHARACTERISTIC FEATURES OF CACTI

By VERA HIGGINS, M A

THAT plants adapt themselves to the environment in which they commonly grow is a well-known biological fact, and, in this connection, the family *Cactaceæ* includes some very interesting examples. The family consists of over 2,000 species and is found, with one possible exception, exclusively in America, extending from latitude 53° N. (Alaska) to latitude 50° S. (Patagonia). Throughout this wide range cacti are found in all situations where the water supply is below normal, and are very considerably modified to meet the adverse conditions under which they live

A study of floral structure and of seedling forms indicates that the *Pereskias* are the earliest type in the family. These plants form straggling shrubs or small trees ; the stems are woody, the leaves broad, evergreen and slightly succulent. Spines occur on the stems, these being in clusters and arising from a woolly protuberance—the areole—a structure which is peculiar to the Cactaceæ and occurs in some form or other in every species , it may possibly represent a modified shoot. The *Pereskias* have been used for so long by the natives as hedge plants that it is difficult now to be sure where they actually occur wild and where they have been introduced, but it is certain that they are all of tropical origin. In the moist tropical forests there occur also the climbing *Cerei*, the *Phyllocacti*, *Rhipsalis* and allied genera ; in these plants the leaves are very much reduced, being represented by small scales which soon fall off, and, in consequence, the stem has taken over the functions of the leaf and is green and bears stomata The stems in these genera are usually flat, triangular or round and either pendent or supported on neighbouring plants. Many species bear aerial roots and some are epiphytic They are found in similar situations to epiphytic orchids and the succulence of the stems is a protection against the drier periods that may occur, when the roots can get little or no water. But since the surrounding vegetation affords more or less protection from the sun and wind, there is not much adaptation of the surface of the stem, which is covered by a thickened cuticle only ; waxy,

hairy or spiny coverings do not occur and such spines as are formed are generally weak and bristle-like.

But the great majority of the cacti are found outside the Tropics, the highlands of Mexico and the plateaux of South America being the areas which are richest in species. In such situations the rainfall is very limited in amount and generally restricted to a short period of the year only; hence, any plant which is to survive such an environment must be considerably modified from the tender-leaved herbs with which we are familiar in temperate climates.

The sphere is the form which has the smallest surface in relation to a given volume, since these plants must store as much water as possible and lose as little as possible by evaporation, cacti tend to become spherical. It is essential for the health of the plant that it should be able to breathe by means of the stomata, but water vapour is also given out through these pores, so they are protected by being sunk in grooves in the plant body. A peculiar phenomenon found in cacti is that, instead of opening during the daytime and closing at night as is the usual process, the stomata remain closed during the heat of the day and open at night, when, if ever, there is dew present

The desert types of cacti never bear leaves when adult, though vestiges may be found in the form of minute scales subtending the areole, the chlorophyll necessary to the chemical processes of nutrition is contained in the stem which is covered by a thickened cuticle; further protection is often afforded by a layer of wax which gives the plant a beautiful bluish colour The clusters of spines found at each areole in most varieties also help to protect the plant; in many cases they are long and interwoven so that they form a network around the plant body, materially reducing the effect of sun and wind on the surface. These spines are also useful in giving protection against browsing animals; cacti being the only juicy things available in a dry country, they would naturally prove very attractive to thirsty cattle, if unprotected. This has proved to be the case with Luther Burbank's "spineless Opuntias"; it was found that, unless given some form of artificial protection, these plants were all devoured before they reached maturity. In times of extreme drought cattle have been known to kick cacti to pieces with their hooves to reach the juicy flesh inside. Even human voyagers in the desert are said to make use of the Visnaga or Barrel Cactus; this plant, as its name implies, is shaped like a cask, about 3 feet high or more; if the top is cut off and the contents well stirred with a stick, a gallon or two of colourless, tasteless liquid can be obtained.

The spines of cacti are very various in form, one or more types being associated together at an areole and are a sufficiently constant feature to be used in identifying species. The central spines, when present, are usually stronger and often of a different colour from the radial ones; and the form of either may be round or flattened, straight or hooked, and variously coloured from white, through yellow, red, brown, purple to black. The areole is usually covered with wool or felt, which in some species disappears with age and in others persists; this also varies in colour and is usually very plentiful at the growing centre of the plant, appearing before the spines and serving as an additional protection to the younger parts.

It has been said that cacti tend to become spherical; there are a very large number of species whose form is spherical or hemispherical; others, which are round in youth, become columnar with age, and may reach a height of 40 or 50 feet or even more. An example of these giants is *Carnegiea gigantea* which forms an important feature in the landscape in parts of south-eastern California, Sonora and Arizona. It branches, the branches arising parallel to the main stem. The flowers are quite small, borne plentifully on the top of each branch, and the little red berries which succeed them are eagerly sought after by the natives.

There seems to be a prevalent notion that cacti do not have many roots; the fact that imported specimens can persist for a long time apparently alive and may even flower without forming new roots, has doubtless given rise to this idea, which however is very far from the fact. In their own habitat, cacti may have enormous root systems, but these are spread over a wide area and usually only a few inches from the surface of the soil, in this way they are able to make the best use of the sudden heavy showers which are so readily absorbed by the thirsty sand. The taller growing species may have a tap-root in addition to the fibrous network, but this does not usually reach any great depth and is more useful in supporting the plant than in conducting water. The root system of a small specimen of *Carnegiea gigantea* 3 feet high was traced out and it was found that four main branches left the base of the stem. One of these appeared to go directly downwards; the other three branched and spread out, having become so fine at about one yard from the plant that they could not be traced further. The roots of a Barrel Cactus, *Echinocactus Wislizeni*, were also mapped out; this plant was about 2 feet high and over one foot in diameter; three main branches left the plant and branched very considerably in all directions; the total distance from the plant at which the roots could be traced was nearly 10 feet, and the mean distance from the surface

of the soil was about 2 inches, though where a stone was encountered the roots dipped below the obstruction, rising again on the other side. One interesting feature was noted; in both these cases the plants were growing on sloping ground and the root development was considerably greater in the uphill direction.

It is obvious that only by drawing on a large area can a desert plant obtain an adequate water supply and this accounts for a noticeable feature of desert vegetation, namely the relatively large distance between the plants, a given species may occur over a considerable area but the individual specimens may be a yard or more apart, the intervening space is either bare or occupied by other xerophytic species, drawing their water supply from a different level.

It is not surprising to find that plants which have become so greatly modified to their environment have also adopted different physiological processes. For growth, it is essential for a plant to obtain carbon from the air in the form of carbon dioxide and this can be accomplished only through the stomata; these breathing pores, when open, permit the evaporation of water vapour from the plant in proportion to the dryness of the surrounding atmosphere. But if the roots can obtain very little water to replace that lost by evaporation it is important that the amount expired as water vapour should not be excessive; hence it is desirable for the stomata to be open to admit carbon dioxide and closed to prevent loss by evaporation and consequently a balance must be struck. Normal plants absorb carbon dioxide by day, in the presence of sunlight this is decomposed by the aid of the chlorophyll so that oxygen is set free and the carbon converted into starches and insoluble sugars. During darkness, these organic substances are again broken down to form simpler soluble compounds, which can be carried through suitable channels and are used to form cellulose; and during this process, excess carbon, again in the form of carbon dioxide, is liberated and given off by the plant. Now it has been found that in cacti the breaking-down process normally carried on during darkness is not carried so far; instead of carbon being set free, organic acids are formed; these are further broken down in daylight and the carbon dioxide then liberated can be immediately used by the plant in the process of photosynthesis, without ever leaving the plant body, and a considerable economy of carbon dioxide is thus effected.

The causes leading to succulence have not been fully investigated but an interesting theory has been advanced. If the water-content of a plant cell is considerably reduced the hexose polysaccharides

are converted into pentosans and these latter compounds have an enormous water-absorbing capacity. Thus great dryness would automatically lead to succulence by a change in the carbohydrate chemistry of the cell, which increases its capacity of retaining water.

It is only natural that such unusual-looking plants as cacti should have attracted the attention of the early explorers of America; in the West Indies is found the Turk's Cap, a large spherical cactus surmounted by a reddish cap shaped like a Turkish fez, on which the flowers are borne, and this species was probably one of the earliest to be introduced to Europe. The first mention of cacti is in Coronado's account of his travels in 1540, and in 1597 Gerarde described two species of cacti in *The Herball or Generall Historie of Plantes*; these were the Turk's Cap, which he calls "Melon- or Hedgehog Thistle," and *Opuntia Ficus Indica*, "The Prickly Indian Fig Tree." In his *Gardener's Dictionary*, 1768 (8th ed.) Phillip Miller mentions about 26 species, most of which he had grown at the Chelsea Physic Garden of which he was curator. When Haworth published in 1819 his *Synopsis Plantarum Succulentarum*, 45 species were recognised, and in 1828 De Candolle records 183 species in 7 genera. Paxton's *Botanical Dictionary* of 1840 gives 400 species as being in cultivation, while Labouret put the number as 670 in 1853. The most important botanical work on the subject of recent years is *The Cactaceæ* by Dr. N. L. Britton and Dr. J. N. Rose, published in 1923. A complete revision of the classification has here been made; the work was undertaken under the auspices of the Carnegie Institute and the funds available made it possible to send collectors to the various districts and also to make careful comparisons of the material existing in Museums and Botanic Gardens all over the world. The result of this critical survey is that whilst a certain number of names in use have been found to be synonymous, it was obvious that species had been included in the same genus although they had little in common. The result is that the authors have thought it advisable to establish a number of new genera, the 24 genera of Schumann's classification being enlarged to 123; while some of these new genera are still disputed, it is obvious that the splitting up of the previous large and heterogeneous groups is definitely advantageous. The total number of species dealt with by Britton and Rose is about 2,000 and since that date (1923) many new species and several new genera have been added. The distribution of cacti—as with other families in the American flora—is often curiously local; a species may occur quite plentifully over a small area and nowhere else; this is especially found to be the case in the mountain ranges; the lower plains are often too warm and

moist for such extreme desert types, which grow plentifully on the higher levels. But this means that there is no intercommunication between the various areas, migration of the species from one range to another being impossible under present climatic conditions. In fact, a mountain chain may be likened to a string of islands as far as plants growing at high altitudes are concerned; and the cactus flora of America exhibits many of the characteristics of island or rather archipelago floras. It is not surprising under such conditions that there are many monotypic genera and Britton and Rose are probably quite justified in their re-division of the family, but considerably more work is required before anything like finality is reached.

The cultivation of such characteristic plants as cacti, away from their natural environment, presents some very pretty problems. In this country, for instance, it is impossible to give the plants anything like the amount of sunshine they are used to. Also, the air in this country is never as dry as it is in desert regions, for this reason, species which will endure frost in their native habitat and even flower through the snow on the high mountain-tops, cannot withstand such low temperatures here, on account of the damp. On the other hand, it is a mistake to think that cacti require great heat. In the early days they were generally plunged in beds of tanner's bark or placed in the stove, which treatment can only have resulted in making them "soft" and non-resistant to decay. For it must be remembered, that cacti are by nature unused to combating diseases caused by minute fungi, since few, if any, of these can exist under the arid conditions of the desert. So that one essential to good cultivation is to see that all sources of decay are reduced to a minimum, houses, staging, pots and so forth being kept scrupulously clean. Growth depends on a combination of sunlight and water supply; since the insolation is so much less in temperate regions, even under the best conditions, the water supply must be nicely adapted to the changed environment. The collecting area being very large under natural conditions, when the roots of a large cactus are confined within a pot, a considerable supply of water is required; it is sometimes thought that cacti can do without water; they can; at least they can exist. A cactus that was kept for two years in a museum case, in dry air at a uniform temperature, started to grow when put into suitable conditions. But without an adequate water supply a cactus cannot grow; to keep it in health it is necessary to recognise a resting-period, when the supply is much reduced or withheld altogether.

The soil in which the desert cacti grow is very loose and sandy

and often contains excess salts owing to the fact that it is not much leached since the rainfall is so small. Lime is nearly always present and is a very useful addition to the potting soil in cultivation. But the characteristic of the natural soil that it is most desirable to imitate in cultivation is the amount of air it contains. Some plants, such as marsh plants, can continue to make root growth when the soil is waterlogged and no free oxygen is available; the roots of other species cease to grow when the oxygen content of the soil is below a certain level, though if the quantity available increases, root growth will recommence. But some species, notably the xerophytic and desert types, have their young fibrous roots and root-hairs killed if the oxygen supply falls below a certain level. Under the unnatural conditions of cultivation, considerably better results are obtained if the desirability of aerating the soil is remembered.

The cultivation of cacti has been pursued more actively on the Continent than in this country; in Germany there are many cactus societies, the most important being the Deutsche Kakteengesellschaft, founded about 1880; in Holland there is a flourishing Society, De Nederl-Vereeniging van Vetplanten-verzamelaars; and Czecho-Slovakia also has an energetic Society formed in 1922. In this country, a Cactus Society formed in 1898 continued in existence for two years only; but the interest in these plants is now considerably on the increase, as is evidenced by the enthusiastic reception of the Cactus and Succulent Society of Great Britain, formed early in 1932.

THE CRYSTAL STRUCTURE OF ALLOYS

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Ever since the application of the microscope to the study of metallic alloys, it has been known that they consisted of a mass of crystals. In more recent years the advent of X-ray crystal analysis following on the discoveries of Laue and W H. and W L. Bragg has placed a new tool in the hands of the metallographer, with the help of which he is able to probe into the interior of the crystal, and examine the way in which its atoms are arranged

By this means it has been shown that solid metallic alloys, unlike liquids and gases, do not contain discrete molecules. Although for convenience one may describe an alloy phase by a simple formula, as for example $CuAl_2$, for the θ-phase of the copper aluminium system of alloys, this does not imply that such alloys in the solid contain separate molecules. This would be impossible from the nature of the crystal structure of $CuAl_2$, which, like that of NaCl, is continuous.

In one important respect alloys differ from inorganic salts. It is not necessary for the ingredients to be present in the exact stoichiometric proportions. In fact, it is sometimes impossible to obtain a homogeneous alloy of exactly the theoretical composition. For example, a homogeneous alloy with the $CuAl_2$ structure must contain a slight excess of aluminium. Such anomalies are constantly to be encountered in the study of metals and alloys, and demonstrate the failure of purely chemical ideas when applied to these bodies. From the standpoint of crystal structure, however, these difficulties are found to be of no consequence.

X-ray crystal structure investigations have shown that the primary feature of all alloys is the existence of a certain type of space lattice. An alloy phase is, by definition, a " homogeneous, physically distinct, and mechanically separable portion " of an alloy system. Crystal analysis shows that the homogeneity of a uniphase alloy is derived from the fact that each atom within the crystal forms part of a single pattern of structure. The physically distinct character of a phase is due to the fact that different phases have

different patterns of structure. Thus in such a typical alloy system as copper zinc we may have phases with face-centred cubic structures, body-centred cubic structures, and other more complicated arrangements [1]. (See Fig. 1.)

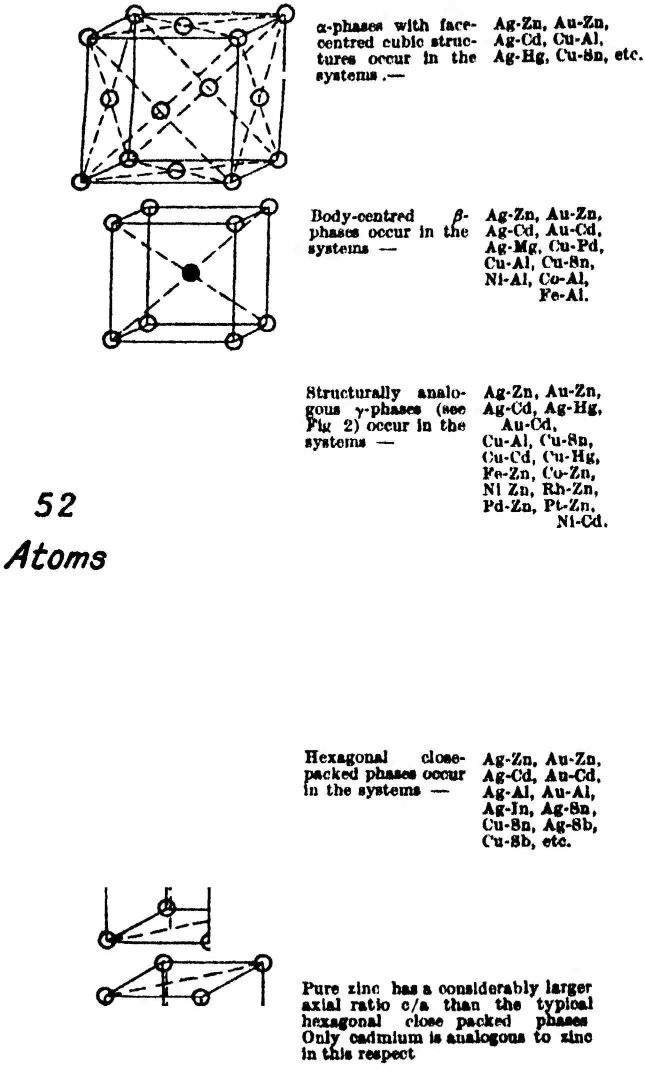


FIG. 1.—Crystal structure of the phases in the copper-zinc system.
(*From Neuberger's Röntgenographie der Metalle und ihrer Legierungen, Ferdinand Enke, Stuttgart.*)

The recognition that the space lattice is the most fundamental feature of alloys has led Hume-Rothery [2] to make a useful classification of alloy phases. In a primary solid solution the atoms have the same crystal structure as the parent metal. For example, on adding zinc to copper to form an alloy of the α-phase, the atoms still retain the face-centred cubic structure characteristic of copper, but some of the atoms are zinc and some copper. In a secondary solid solution, the crystal structure is different With the addition of more than about 40 per cent. of zinc, the α-phase reaches saturation, and a second phase makes its appearance. This is the β-phase with a body-centred cubic structure. Other secondary solid solutions of copper and zinc are the γ-phase which has a complicated type of cubic structure, with 52 atoms in the unit cell, and the ϵ-structure which is hexagonal close-packed.

In order to explain the occurrence of phases at analogous compositions in different alloy systems, Hume-Rothery [3] took up the suggestion that an alloy consisted essentially of a combination of electrons and atoms. The copper atoms in metallic copper lie on a face-centred cubic lattice like the sodium atoms in sodium chloride. In the salt each metallic atom is separated by an atom of chlorine ; in the metal the space between the neighbouring atoms may be supposed to be occupied by valency electrons. This idea led to the view that there should be a definite relation between the number of valency electrons and the number of atoms. The idea was originally applied by Hume-Rothery to the alloy phases with the approximate compositions CuZn, Cu_3Al, and Cu_5Sn, but since then it has been shown to have a much wider application. It is now known that each of the above alloys has a body-centred cubic lattice. According to Hume-Rothery, this analogy in structure is to be expected from the fact that each of the above compounds has a ratio of 3 valency electrons to 2 atoms. Copper is here reckoned monovalent, zinc divalent, aluminium trivalent, and tin tetravalent.

This brilliant suggestion was taken up by Westgren and Phragmen [4], who showed that a great number of alloy phases in very different systems follow Hume-Rothery's rule. Five different types of crystal structure occur to which it is possible to ascribe a certain ratio of valency electrons to atoms. For the validity of the rule it is necessary to suppose that for each atom the valency electrons are those in excess of the number required to fill a given electron shell. For example, aluminium [13] has three electrons more than are required to fill the neon shell [10]; copper has one more than is required to fill the nickel shell [28]; for palladium [46] the last shell is just filled and there are therefore no valency electrons avail-

able. In the case of the metals of the 8th group of the periodic table for which the shells are not quite filled (*e.g.* iron and cobalt) the valency is reckoned as zero. In many cases where the electron ratio is 3 · 2 a body-centred cubic structure has been found, for example CuZn, AgZn, Cu_3Al, Cu_5Sn, NiAl, FeAl; with a ratio of 21 : 13, a complex cubic structure [5] (see Fig. 2) is found, *e.g.* Cu_5Zn_8, Cu_9Al_4, $Cu_{31}Sn_8$, Fe_5Zn_{21}, Pt_5Zn_{21}, 7 : 4, close-packed hexagonal, *e.g.* $CuZn_3$, Cu_3Sn, 5 : 2 or 6 : 2 a hexagonal structure, *e.g.* NiAs, FeS, CoS, lastly, 4 : 1 structures like FeS.

Each of the above five types of structure may occur in any of the alloy systems containing a metal of a transition element, and an element belonging to the B sub-groups of the periodic table. For

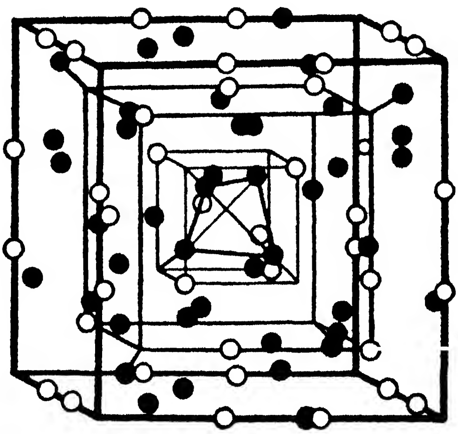


FIG. 2.—Crystal Structure of Cu_5Zn_8.
(*From Neuberger, loc. cit.*)

example, the transition element may be iron or copper, the element of the B sub-group may be zinc or tin. It has recently [6] been shown that this rule may also be extended to alloys of the alkali metals, an alloy of the composition $Na_{31}Pb_8$ having been found to have a structure of the γ-brass type (Fig. 2), but with a double unit, like $Cu_{31}Sn_8$. The rule has, however, not by any means a universal application. Some of the five typical phases are missing from almost every system so far examined, and in certain systems there are other phases of quite a different type. In the silver-aluminium system the only secondary phases found were a hexagonal close-packed structure and a type of cubic structure with a unit cell containing 20 atoms. This structure is exactly like that of the β-form of the element manganese [7], and there is as yet no explana-

tion of its occurrence in alloy systems. It is often found instead of the body-centred cubic structure when the ratio of electrons to atoms is 3 : 2. The alloys Ag_3Al, Au_3Al, $CoZn_3$ and Cu_5Si all have this type of structure. The copper-aluminium [8] system is quite different from the silver-aluminium system. Here the β-phase with an electron ratio of 3 : 2, which is only stable above 600°, has a body-centred cubic lattice, and there is no hexagonal close-packed structure. This a good illustration of the general rule that in alloy systems chemical analogy between elements does not necessarily lead to the formation of analogous phases. The resemblance between the silver-zinc and the copper-aluminium systems is much greater than the resemblance between the silver-aluminium system and either of these two. It appears that in alloys the chemical nature of individual atoms is subordinated to the lattice as a whole.

The Hume-Rothery rule predicts only the atomic positions ; it does not tell how the atoms are distributed in those positions. In fact an ordered arrangement only occurs in certain cases. With the β-Mn type of structure it is impossible to divide up the atoms of different kinds in any regular manner, except in the ratio of 8 : 12 which does not correspond to the atomic proportions of any of the alloys having the β-Mn type of structure ; atoms of different kinds are therefore distributed at random. In other cases it is easy to see that the nature of the crystal structure lends itself readily to an ordered arrangement of the different types of atom. For example, an alloy of the type XY with a body-centred cubic lattice is almost certain to be found with X atoms and Y atoms occupying definite positions. Atoms of one kind occupy cube corners, and those of the other cube centres (as in Fig. 1). This arrangement is like the cæsium chloride structure in which cæsium atoms occupy cube corners and chlorine atoms cube centres. There is, however, an important difference. The atoms in CsCl occupy regular positions by necessity ; positive and negative ions must alternate. For alloys it is merely a matter of convenience, and it does not matter if a few of the atoms get in the wrong places, because there is not likely to be much difference in potential energy whether the atoms are in the wrong places or the right ones.

It is interesting to examine what happens when there are not quite the correct numbers for the complete development of the regular arrangement of atoms. This problem has been investigated in the case of the alloy FeAl [9]. In accordance with the Hume-Rothery rule, this alloy has a body-centred cubic structure, and if there are exactly equal numbers of iron and aluminium atoms, the former occupy cube corners, and the latter cube centres. It is of

course arbitrary which are called corner atoms and which centre atoms ; since the whole structure is continuous, the corner of one cube is the centre of another cube. The essential feature of the arrangement is that no aluminium atom has another aluminium atom as its nearest neighbour, and no iron atom has another iron atom as its nearest neighbour. This rule can only be observed rigidly if there are exactly equal numbers of iron and aluminium atoms. With an excess of iron atoms, two iron atoms must come into close contact. If the atoms were oppositely charged ions like sodium and chlorine in NaCl, this would be impossible, and the excess of iron would be ejected from the phase. In FeAl, any iron atoms which are in excess replace aluminium atoms at cube centres. Suppose that an alloy is prepared with 40 atomic per cent. of aluminium. Out of every 100 atoms occupying centre positions in the crystal 80 atoms are aluminium. A hundred of the iron atoms occupy every available corner position. The remainder of the iron atoms fill the vacant positions at cube centres.

Another respect in which alloy structures differ from salt-like compounds is shown by the ease with which the regularity of the arrangement is destroyed. Schäfer [10] has recently found that if an alloy of the composition FeAl be ground up into a fine powder in a steel mortar, an X-ray powder photograph shows that the regular arrangement of iron and aluminium atoms has been destroyed. The ordered arrangement is, however, restored if the alloy is heated to a suitable temperature. This experiment illustrates the well-established fact that the presence of ordered arrangements is very dependent on the heat treatment given to the alloy.

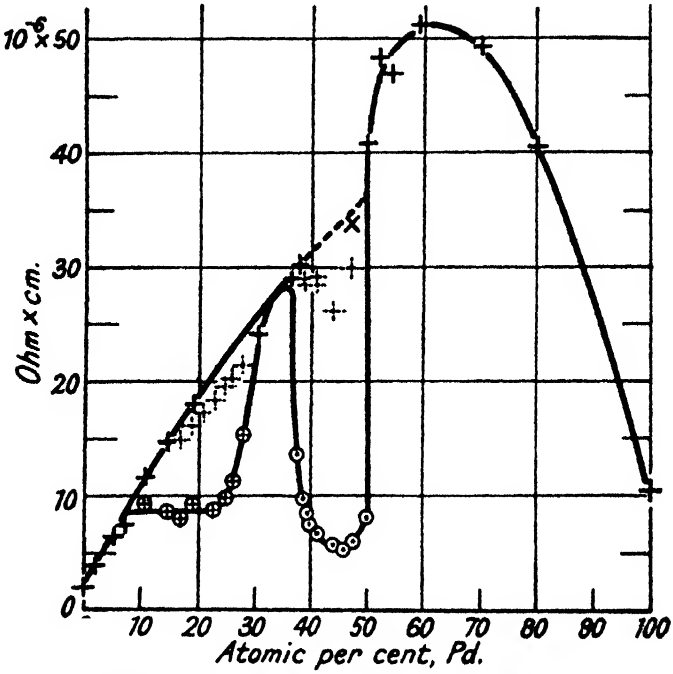
A well-known example is the behaviour of copper-gold and similar alloys, which has been thoroughly examined by Johansson and Linde [11], and others. These alloys do not belong to the same category as those hitherto considered. They may be classified under the general heading of binary alloys in which both metals belong to the transition series, which for the purpose of classification of the alloy systems includes the metals Cu, Ag, and Au. For the most part there are no intermediate phases except when the alloy is specially treated and Hume-Rothery's rule has no application here. In most instances these alloy systems contain extensive areas of solid solution, often stretching continuously across all compositions at high temperatures. This is, of course, only possible where there is no great change in crystal structure between the elements. Alloys of this class when cooled quickly as, for example, by chill-casting, by quenching from above 600°, or even by cooling over a period of several hours, show only the same type of X-ray pattern

as the parent metals. Alloys of the copper-gold series have a face-centred cubic lattice like pure copper or pure gold, on which the atoms of copper and gold are distributed in a random manner, so that any point in the lattice may be occupied either by copper or by gold. However, by a suitable heat-treatment, alloys of certain approximate compositions (*e.g.* $AuCu_3$, AuCu, CuPd, Cu_3Pd) may be induced to conform to an ordered arrangement. For this purpose it is usually necessary to keep the temperature at 300° to 400° for several days. During the transformation there is a big fall in electrical resistance. In the original solid solution without the superlattice the resistance is much greater than in the pure metals gold and copper, but in the heat-treated alloy, the assumption of the ordered state with the superlattice is accompanied by a return to the electrical and mechanical properties of a pure metal. This is illustrated by Fig. 3, showing the relation of electrical conductivity to heat treatment, in the copper-palladium system.

On theoretical grounds Zemczusny and Zasedatelev [12] had previously suggested that the transformation at the compositions X_3Y and XY in the equilibrium diagram of all such systems should be represented in the manner shown in Fig. 4. At temperatures above the line *abe* the alloy in equilibrium has no superlattice. At temperatures below the line *adc*, the alloy in equilibrium exists in the ordered state. If the change from disorder to order were a genuine change of phase, in accordance with thermodynamic principles the diagram should have a two-phase region, *e.g.* an alloy allowed to cool along a line *bc* should break up into two phases at all temper-tures corresponding to points between *b* and *c*. There is, however, no X-ray evidence in support of this point of view. The transition from an ordered to a disordered state, and the reverse process, are apparently gradual changes which should not be represented by definite phase boundaries. Heterogeneous equilibrium must necessarily occur only when the crystal structures of the ordered and disordered states are entirely different. For example, in the copper-palladium system, annealing transforms the face-centred cubic solid solution of 50 per cent. copper and 50 per cent. palladium into a body-centred cubic lattice with copper atoms at the cube corners, and palladium atoms at the cube centres. Here there must be conditions under which the face-centred structure and the body-centred cubic structures will coexist.

L. Graf [13] has recently shown that the transformation in the alloy AuCu proceeds in two stages. As the temperature is gradually lowered into the range where ordered arrangement becomes possible, the lattice symmetry first changes from cubic to tetragonal, and

afterwards the atoms begin to sort out. It was already known from the work of Ohshima and Sachs [14] and of Gorsky [15] that the transformation from the cubic to the tetragonal structure takes place instantaneously, the axial ratio changing suddenly from 1·00 to 1·07. It is possible that the cubic phase and the tetragonal phase



+ Cubic face-centred, without superlattice.

⊕ Cubic face-centred, with superlattice, tempered alloy.

⊙ Cubic body-centred, with superlattice, tempered alloy.

+ Rapidly cooled from melting point, not annealed.

× Quenched alloy, crystal structure badly formed.

FIG. 3.

(C. H. Johansson and J. O. Linde, Ann. d. Phys., 82, 454, 1928.)

may coexist, but this is not yet known with certainty. If it should be established, the boundaries on the diagram of Zemczusny and Zasedatelev would probably correspond to the change from cubic to tetragonal structures. The development of the ordered state might then occur at any point within the area corresponding to the tetragonal structure.

It is possible that the change from the disordered to the ordered state may take place simultaneously at a number of different centres

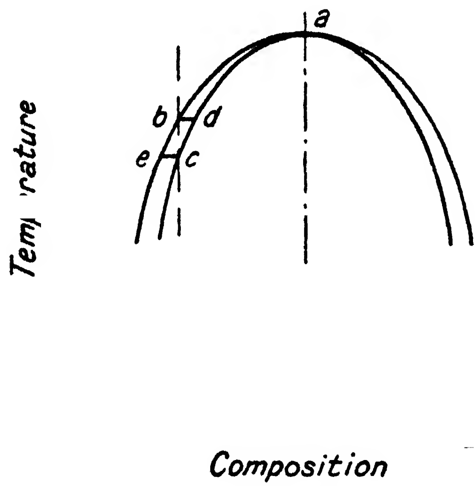


FIG. 4.

(G. Borelius, C. H Johansson and J. O Linde, Ann. d. Phys, 86, 306, 1928)

in each crystal. If so, an arrangement is possible similar to that shown in Fig. 5, taken from a paper by Borelius, Johansson, and

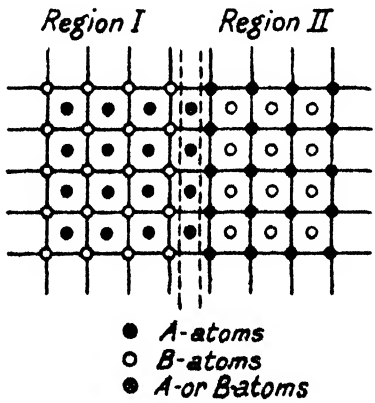


FIG. 5.

(G. Borelius, C. H. Johansson and J. O. Linde, loc. cit.)

Linde [11]. Calculation shows that such an arrangement, where opposite distributions occur in different parts of the crystal, cannot be distinguished by X-ray methods from a completely disordered

structure. It is, therefore, possible that the preliminary change from the cubic to the tetragonal structures coincides with the formation of small ordered regions in different parts of the crystal, and that the subsequent development of new X-ray reflections is due to a realignment of atoms in which the whole of each crystal becomes homogeneous.

The change from the disordered to the ordered state may be accompanied by a contraction in lattice spacing, as in the case of $AuCu_3$, Fe_3Al, CuPd. Cu_3Pd, on the contrary, shows no change in spacing in the ordered and disordered states. In the case of Fe_3Al [16] the contraction was of the order of 0·1 per cent. An X-ray photograph of an alloy of the composition Fe_3Al quenched in water

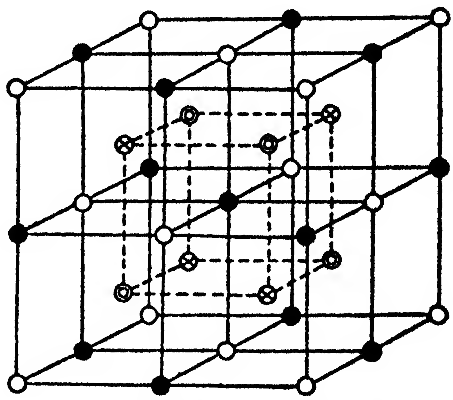


FIG. 6.—Fe_3Al structure.

from a temperature of 600° showed only the reflections characteristic of a body-centred cube, and gave a lattice spacing 2·8944Å, but on annealing and slowly cooling the alloy between 600° and 300°, the powder photographs indicated that the atoms had the arrangement shown in Fig. 6, in which B atoms were aluminium and A, C, D atoms were iron. The lattice spacing of each body-centred cube had now contracted to the value 2·8904Å.

Such experiments indicate that the formation of ordered arrangements permits a more economical adjustment of the atoms. Whether this should be ascribed to the greater attraction between atoms of different kinds, or whether it is a question of the relative sizes of the atoms is not yet known. Atomic size is of tremendous importance in all crystalline bodies, but especially in connection with the

metallic alloys. Modern views about the nature of binding forces between atoms, and calculations of lattice energy, show that the conception of atomic radius first introduced by W. L. Bragg [17] has a real physical significance. There are very definite limits to the distances between atoms in crystals. The most stable condition in an alloy, corresponding to the least potential energy, will usually be attained when each atom has approximately its normal inter-atomic distance, *i.e.* the distance between the atoms in the pure metal. In an alloy this may be attained either by a symmetrical packing of atoms, as in the annealed copper-gold alloys, or by a distortion of the lattice. A picture of lattice distortion in alloys is shown in Fig. 7 which is due to Sachs. It shows the effect of

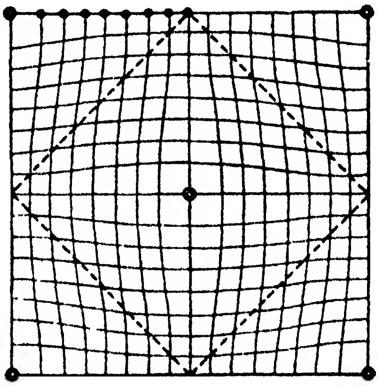


FIG. 7.—Lattice displacement in the neighbourhood of a dissolved atom (Sachs).
(*J. Hengstenberg, "Ergebnisse der technischen Röntgenkunde," Bd II, p.* 150, 1931, *Akademische Verlag m. b. H., Leipzig*)

adding a foreign atom of larger size to a metal in which it is soluble. There are limits to the amount by which a lattice may be distorted; this is one of the principal factors limiting solid solubility.

Continuous ranges of solid solution are possible even when the elements have not the same crystal symmetry, provided the atoms are not too different in size, and the structures are similar. In the copper-manganese system we have a case in point. Pure copper is face-centred cubic; whereas manganese, on the other hand, exists in three modifications. Two of these, α-manganese, and β-manganese are cubic, but the structures are very complicated. The third, γ-manganese, is tetragonal. Although formed by electrolysis, it is metastable at room temperatures. It becomes the stable form at 1191°, and above this temperature forms a continuous series of

solid solutions with copper. By the addition of copper to manganese the axial ratio is gradually increased from the value 0·934 for pure manganese to unity when the copper content reaches about 25 per cent. Between about 25 per cent. Cu and 100 per cent. Cu the alloys are all cubic. A similar change was found by Ohman in the γ-phase of the iron manganese system, which is illustrated in Fig. 8. The upper diagram shows the relation of lattice spacing to composition in the γ-phase. In the tetragonal region to the right of this diagram there are two values for the spacing corresponding to the lengths of the c and a axes. In the cubic region the lengths are, of course, equal. Ultimately it may be found that there are narrow ranges of discontinuity near the point where the tetragonal structure merges into the cubic structure. Until then such alloys can be considered to form a continuous series of solid solutions.

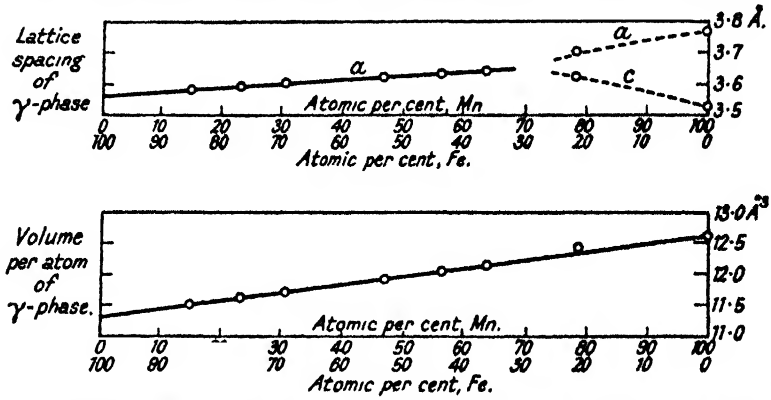


FIG. 8.—The change in lattice spacing and the volume per atom of the γ-phase with composition.

(Öhman, *Z. phys. Chem.*, 8, 88, 1930.)

In the lower diagram the volume per atom is plotted against the atomic composition. This curve is practically linear, and is a good illustration of the rule that the mean atomic volume of an alloy is, to a first approximation, an additive quantity, and may be calculated from the law :—

$$100.\ V_x = x.\ V_a + (100 - x).\ V_b,$$

where V_x is the mean atomic volume of an alloy containing x atomic per cent. of a metal of atomic volume V_a, and $100 - x$ atomic per cent. of a metal of atomic volume V_b. This law is, in most instances, only a rough approximation. Westgren and Phragmen [18] [19] have shown that there is, in many instances, a contraction of the alloy lattices. In some systems the contraction is slight, *e.g.* in the systems CuZn, AgZn, and AgCd. In other cases, for

example in the NiAl system, a very marked contraction occurs, especially around the composition NiAl. Recently an investigation of the copper-palladium system has shown that the lattice spacings in this system are consistently high.

So far we have only discussed those alloys in which the atoms of the solute element replace those of the solvent atom when entering into solid solution. There is, however, another class of alloys in which the solute atoms are small enough to slip between the atoms of the solvent. These alloys are confined to the systems consisting of transition elements on the one hand, and the small atoms H, B, C, and N, on the other. The simple type of interstitial replacement is only possible to any great extent when the ratio of the diameter of the metal atom to that of the non-metal atom exceeds 1·7 [20]. Three types of structure commonly occur in this case :—face-centred cubic, hexagonal close-packed, and a simple hexagonal type. Deformed structures of lower symmetry are also known. If the ratio is less than 1·7 the alloys usually form complicated structures, *e.g.* cementite Fe_3C.

The structures of austenitic and martensitic carbon steels [21] belong to the interstitial class of alloy. In austenite, the iron atoms form a face-centred cubic lattice (γ-iron), and the smaller carbon atoms are inserted in the interstices between the iron atoms. This structure is only stable at fairly high temperatures, and on cooling the alloy a structural transformation occurs. The iron atoms change over to a body-centred cubic lattice (α-iron). This type of structure does not contain interstices of suitable size and shape to hold the carbon atoms, which are consequently ejected from the iron lattice, and go to form a compound cementite, whose crystal structure has recently been determined. This process requires time for completion, and if the alloy is cooled quickly by quenching, the carbon atoms have not time to escape from among the iron atoms. Their presence distorts the α-iron lattice, which becomes tetragonal instead of cubic. This tetragonal structure which is intermediate between a face-centred cube and a body-centred cube in type is known as martensite, and is one of the most important constituents in quenched carbon steels.

Alloys of similar type to the austenitic and martensitic carbon steels may be formed by the solution of nitrogen in iron [20] [22]. On the first addition of nitrogen the lattice is expanded without change of type. This process, which only proceeds up to 0·2 per cent. N, in the case of the body-centred cubic α-phase which is the stable form at room temperatures, may be continued up to 3 per cent. N, in the case of the face-centred γ-form at 900°. If now a face-

centred γ-alloy containing 1·5 per cent. N be quenched from a suitable temperature, a tetragonal phase similar to martensite is produced. The analogous behaviour of carbon and nitrogen in this respect has nothing to do with the chemical properties of these elements. It is entirely a matter of size. Carbon and nitrogen are small enough to get between the iron atoms without disturbing the face-centred cubic structure. Elements such as silicon and phosphorus which are chemically similar to carbon and nitrogen are unable to form alloys of the interstitial type because they are too large. In these cases substitution proceeds in the more usual manner, an atom of silicon replacing an atom of iron.

A somewhat analogous case to the austenite-martensite transformation has recently been discovered in the copper-aluminium system of alloys by means of X-rays. The β-phase of this system has been investigated at high temperatures [23], and has been found to have a body-centred cubic structure above 600° C. It has been supposed that the copper and aluminium atoms have an ordered arrangement at these temperatures corresponding to the formula Cu_3Al, but no direct experimental evidence has been adduced in support of this view. In any case there is no doubt about the body-centred cubic lattice. It is equally certain that if the alloy is slowly cooled down to room temperature, or heated for some hours below about 570°, the body-centred cubic structure is decomposed into a mixture of the α-face-centred cubic phases and the δ-phase which has a complete cubic structure with 52 atoms in the unit cell [5]. The transformation of β-CuAl to a mixture of the α- and δ-phases, like the transformation of austenite to α-iron, and cementite (Fe_3C), does not take place instantaneously. If the alloy is cooled quickly, for example by quenching in cold water, a new type of structure (β') [23] is formed. The β' alloy is metastable, and like martensite, must be considered to be an intermediate stage in the decomposition of the form stable at a high temperature. It undoubtedly bears a close crystallographic relationship to the face-centred α-phase, but is more complex in character. The β–β' transformation may be prevented by the substitution of some manganese for copper in the β-alloys. It is remarkable that the austenite-martensite transformation in steel is also prevented by the addition of manganese, although here the transformation is from a face-centred cubic structure towards a body-centred cubic structure, whereas in the case of the β-CuAl transformation the change is from a body-centred cubic structure towards a face-centred cubic structure.

As a further example of the application of crystal analysis to the study of transformation, mention may be made of the recent

work of Owen and Pickup [24] on the copper-zinc system. It has been supposed that a transformation occurred in the β-phase of the copper-zinc system, at a temperature of about 470°. X-ray investigation has shown that there is no difference in the crystal structure above and below this temperature. They now suggested that the thermal effects which had been observed in β-alloys are due to heat of solution, caused by a change in solubility at about 470°.

In conclusion, it is desirable to state that no attempt has been made to make the present account comprehensive. There is not space in an article of this length to give more than a brief selection of some of the most interesting of the direct applications of crystal analysis to metallurgical problems.

REFERENCES

1. A. Westgren and G. Phragmen, *Phil. Mag.*, **50**, 331, 1925; *ibid.*, *Trans. Farad. Soc.*, **25**, 382, 1929.
2. W. Hume-Rothery, *Phil. Mag.*, **5**, 173, 1928.
3. W. Hume-Rothery, *J. Inst. Metals*, **35**, 295, 1926.
4. A. Westgren and G. Phragmen, *Metallwirtschaft*, **7**, 700, 1929; *Trans. Farad. Soc.*, **25**, 379, 1929; *Metallwirtschaft*, **9**, 919, 1930; *Z. Metallkunde*, **22**, 368, 1930.
   A. Westgren and W. Ekman, *Arkiv. f. Kem.*, etc., **10** B No. 11, 1930.
5. A. J. Bradley and J. Thewlis, *Proc. Roy. Soc.* A, **112**, 678, 1926.
   A. J. Bradley and C. H. Gregory, *Phil. Mag.*, **12**, 143, 1931.
   A. J. Bradley and P. Jones, *Journ. Inst. Met.*, 1933.
6. C. W. Stillwell and W. K. Robinson, *J. Amer. Chem. Soc.*, **55**, 127, 1933.
7. G. D. Preston, *Phil. Mag.*, **5**, 1207, 1928.
8. E. A. Owen and G. D. Preston, *Proc. Phys. Soc.*, **36**, 14, 1923.
   Jette, Westgren and Phragmen, *Journ. Inst. Met.*, **31**, 193, 1924.
9. A. J. Bradley and A. H. Jay, *Proc. Roy. Soc.* A, **136**, 210, 1932.
10. K. Schäfer, *Naturwis*, private communication, 1933.
11. C. H. Johansson and J. O. Linde, *Ann. d. Phys.*, **78**, 439, 1925; *ibid.*, **82**, 449, 1927.
    G. Borelius, C. H. Johansson and J. O. Linde, *Ann. d. Phys.*, **86**, 291, 1928.
12. N. Kurnakow, S. Zemczusny, and M. Zasedatelev, *J. Inst. Met.*, **155**, 305, 1916.
13. L. Graf, *Z. Metallkunde*, **24**, 248, 1932.
14. K. Ohshima and G. Sachs, *Z. f. Phys.*, **63**, 210, 1930.
15. W. Gorsky, *Z. f. Phys.*, **50**, 64, 1928.
16. A. J. Bradley and A. H. Jay, *J. Iron and Steel Inst.*, No. 1, 339, 1932.
17. W. L. Bragg, *Phil. Mag.*, **40**, 177, 1920.
18. A. Westgren and G. Phragmen, *Trans. Farad. Soc.*, **25**, 384, 1929.
19. A. Westgren and A. Almin, *Z. Phys. Chem.*, **4**, 14, 1929.
20. G. Hagg, *Z. Phys. Chem.*, **6**, 221, 1929; **7**, 339, 1930.
21. N. Seljakow, G. Kurdjumov, and N. Goodzow, *Z. Phys.*, **45**, 384, 1927.
    G. Kurdjumow and G. Sachs, *Z. Phys.*, **64**, 325, 1930.
22. O. H. Eisenhut and E. Kaupp, *Z. f. Elektro.*, **36**, 392, 1930.

23. E. Persson, *Naturwis*, **61**, 613, 1928.
I. Obinata, *Mem. Ryojun Coll. Eng.*, **3**, 285, 295, 1929.
N. Ageew and G. Kurdjumow, *Phys. Z. Sowjet Union*, **2**, 146, 1932.
A. J. Bradley and P. Jones, *Journ. Inst. Met.*, **51**, 131, 1933.
24. E. A. Owen and G. D. Preston, *Proc. Roy. Soc.*, **36**, 49, 1924.
E. A. Owen and L. Pickup, *Proc. Roy. Soc*, **140**, 191, 1933.

RECENT ADVANCES IN SCIENCE

APPLIED MATHEMATICS. By Professor F. E. Relton, D.Sc., M.A., Royal School of Engineering, Giza.

Hydrodynamics.—The question of frictional resistance has been treated at some length by F. Eisner, " Reibungswiderstand " (Hamburg, Sitz. v. 18–19, V, 1–49, 1932). It is difficult to summarise the paper, as it is a collected report. With the author's wonted thoroughness the extensive literature of the last ten years, or thereabouts, is sifted and discussed. Chief place is given to deciding what part of the total resistance of a moving body is to be ascribed to friction. Prominence is also given to the transition from the plane to curved surfaces. On certain mechanistic hypotheses, acceptable results for the former are obtainable by means which are in part theoretical and in part empirical. The author is concerned with deciding how far these hypotheses and considerations can be transferred to surfaces which, in practice, are necessarily curved, as is the case with ships.

With the same reference, pp. 50–73, Th. v. Kármán discusses " Theorie des Reibungswiderstandes " in a manner which differs from the precursor in giving greater prominence to the theoretical aspect. Chief place in the discussion is given to the difference between laminar and turbulent boundary layers.

Anyone who has had occasion to stand near high-velocity gunfire knows only too well the distressingly sharp crack of the *onde de choc*, so different from the relatively dull report of the gun. Photographs of bullets in flight show very clearly the existence of this surface, where a sharp change of density and velocity occurs. The subject was first investigated by the versatile Rankine ; but his work was ignored, and the phenomenon is now usually associated with the name of Hugoniot. In the *Proc. Roy. Soc.* A, **139**, 278–311, 1933, appears " The Air Pressure on a Cone Moving at High Speeds—I." The numeral presumably indicates that there is more to follow ; the authors are Taylor and Maccoll, with fitting acknowledgments to the N.P.L., the Research Department of Woolwich Arsenal, and others. In substance, numerical integration of the

equations of motion is carried out for cones of three different vertical angles. It appears that the shock wave is attached to the point of the projectile provided the latter's velocity exceeds a certain multiple of the velocity of sound. This multiple increases with the angle of the cone, and at lower speeds the shock wave detaches itself and travels ahead of the projectile. One case has been substantiated by Harris's ingenious photographs of bullets in flight; the calculated values of the pressures compare very favourably with the wind tunnel results obtained by Gough and Bailey at the N.P.L.

A further and very brief contribution to the study of the compressible fluid comes from D. Riabouchinsky, "Sur l'analogie hydraulique des mouvements d'un fluide compressible" (*C. R. Acad. Sci. Paris*, **195**, 998–9, 1932). Taking the equation for two-dimensional motion of a compressible fluid

$$\left(\frac{\rho}{\rho_0}\right)^{x-1} = 1 - \frac{x-1}{2}\left(\frac{q}{c_0}\right)^2$$

where x is usually 1·41 for gases, the value $x = 2$ leads to comparison with the hydraulic relation

$$\frac{h}{h_0} = 1 - \tfrac{1}{2}\left(\frac{q}{c_0}\right)^2, \quad c_0^2 = gh_0.$$

There is brief reference to experimental researches on the analogy.

Heaviside's operational methods, which at the present time are very much to the fore, have been ably applied by S. Goldstein, writing on "Some Two-dimensional Diffusion Problems with Circular Symmetry" (*Proc. Lond. Math. Soc.*, II, **34**, 51–88, 1932). In spite of its title, it is not concerned with osmotic pressure or colloids, and a good half of the paper deals with hydrodynamics. It follows, in essentials, the treatment of heat-conduction problems by Bromwich, and the assumed circular symmetry naturally entails the liberal use of Bessel functions, the operator appearing in the argument. This paper will well repay careful study, and many of its results are new.

Reference must be made to two papers on existence theorems. The first is a very brief one by Leon Lichtenstein "Über einen Stetigkeitssatz in der Hydrodynamik. Eine Begründung der Helmholtz-Kirchhoffschen Theorie geradliniger Wirbelfäden" (*Commun. Soc. Math. Kharkow et Inst. Sci. Math. Ukraine*, IV, **5**, 7–9, 1932). The second, which continues some of the author's previous work, is by T. Levi-Civita "Teoremi di unicità e di esistenza per le piccole oscillazioni di un filetto vorticoso prossimo alla forma circolare" (*Atti Accad. naz. Lincei, Rend.*, VI, **15**, 409–16, 1932). The existence of the solution of the fundamental equation, with certain initial conditions, is first established; its uniqueness is then proved by

the use of Almansi's lemma. This lemma is freely used by Italian writers, and as I shall later refer to it again, in my remarks on Elasticity, I may as well give it here. Given a continuous function, whose average value over a certain range is zero, the integral of its square can be compared with the integral of the square of its derivative over the same range. It is usually employed in the form

$$\int_0^a \left(\frac{du}{dx}\right)dx = 0, \quad \int_0^a \left(\frac{du}{dx}\right)^2 dx < \left(\frac{a}{2\pi}\right) \int_0^a \left(\frac{d^2u}{dx^2}\right)^2 dx.$$

Elasticity.—The problem of the clamped rectangular plate, subjected to edge thrust, has been discussed by K. Sezawa, "Das Ausknicken von allseitig befestigten und gedrückten rechteckigen Platten" (*Z. angew. Math. Mech,* **12,** 1932). Taking rectangular axes parallel to the sides of the plate, the deflection w is to be determined from

$$N\nabla^4 w + P_1\frac{\partial^2 w}{\partial x^2} + P_2\frac{\partial^2 w}{\partial y^2} = 0.$$

The solution is assumed to consist in two types of term, *i e.* $W_1(y)$, a function of y alone, with a sine or cosine factor whose argument is a multiple of x; plus $W_2(x)$ with a corresponding factor in y. The functions W_1, W_2 then satisfy ordinary fourth-order differential equations with constant coefficients. The difficulty of simultaneously satisfying the whole of the boundary conditions is obviated by a modification. The deflection is taken as zero all round the periphery; but the edge-slope is taken to be zero only at specified points. The critical pressures are then found by trial, after adopting an arbitrary value of the ratio P_1/P_2. It would be interesting to know whether the method is more reliable and less laborious than that given by Timoshenko. His method is applicable to a wide range of problems in elastic instability, and was published in *Ann. des Ponts et Chaussées,* **17,** 372–412, 1913.

The rôle of harmonic functions has received attention in two related papers by P. F. Papcovitch. The first is a "Solution générale des équations différentielles fondamentales d'élasticité, exprimée par trois fonctions harmoniques" (*C.R. Acad. Sci. Paris,* **195,** 513–15, 1932). The three harmonic functions are B_1, B_2, B_3, components of a vector $\mathbf{B}$. The position vector $\mathbf{r}$ has components x, y, z. The equation

$$\nabla^2\mathbf{V} + \frac{1}{1-2\sigma}\nabla\nabla.\mathbf{V} + \frac{1}{\mu}\mathbf{F} = 0$$

then has the solution

$$\mathbf{V} = \mathbf{V}_0 + \mathbf{B} - \frac{1}{4(1-\sigma)}\nabla\mathbf{r}\cdot\mathbf{B}$$

where V_0 is a particular solution. This is a generalisation of results previously obtained by various writers. The sequel is "Expressions générales des composantes des tensions, ne renfermant comme fonctions arbitraires que des fonctions harmoniques" (*C.R. Acad. Sci. Paris*, **195**, 754–6, 1932). Here the previous formulæ are generalised by the introduction of a fourth harmonic function, and expressions are given for the six stress components. In the case where the body forces are absent, the solution can be reduced to that due to Galerkin.

A number of Italian papers call for notice. Pietro Teofilato writes on "Un limite superiore dei periodi propri di vibrazioni" (*Atti Pontif. Accad. Sci. Nuovi Lincei*, **85**, 309–19, 1932). In the case of a freely supported beam, the solution of

$$\rho\frac{\partial^2 y}{\partial t^2} + \frac{\partial^2}{\partial x^2}EI\frac{\partial^2 y}{\partial x^2} = 0$$

is taken in the form $y(x, t) = \Sigma_\kappa q_\kappa(t)f_\kappa(x)$. A discussion of this solution, particularly as regards $f(x)$, leads to the result

$$T_{max} < 5\cdot15A_0l^2\sqrt{\frac{\rho}{E}}.$$

Closely related to this in outlook is G. Lampariello's work "Sull' equazione delle vibrazioni trasversali di un'asta elastica sollecitata agli estremi" (*Atti Accad. naz. Lincei, Rend.*, VI, **16**, 102–5, 1932). The equation

$$\frac{\partial^4 u}{\partial x^4} + \frac{\partial^2 u}{\partial x^2} + \frac{d^2 u}{\partial t^2} = 0$$

with the given end conditions, leads to

$$\int_0^a\left(\frac{\partial u}{\partial t}\right)^2 dx = \int_0^a\left[\left(\frac{\partial u}{\partial v}\right)^2 - \left(\frac{\partial^2 u}{\partial x^2}\right)^2\right]dx.$$

If the right-hand side proves to be essentially negative, it follows that $\partial u/\partial t$ must be zero throughout the range of integration. This is where use is again made of the previously mentioned lemma of Almansi. The result is applied to a doubly encastrée beam, of length not exceeding Euler's critical length.

Enrico Volterra uses the analogy between elasticity and electricity in "Perturbazione prodotta da più sfere rigide in un mezzo elastico in equilibrio" (*Atti Accad. naz. Lincei, Rend.*, VI, **13**, 32–7, 1931). In a later issue of the same journal (VI, **16**, 220–2, 1932) Volterra proposes, in order to get useful approximate solutions to elasticity problems, that we make general assumptions on the type of deformation. The arbitrary functions appearing in these attempts

are to be defined by variational means. The relation to existing methods is briefly mentioned, and what is more important, a further contribution is promised, with worked examples. The title of the paper is "Elasticità vincolata e sua schematizzazione matematica."

MECHANICS.—The problem of three bodies, together with its related problems, continues to attract attention in its many modified forms. Two recent papers occur consecutively in the same journal, *Trans. Amer. Math. Soc.*, **34**, 1932. The first, by C. J. Coe, occupies pp. 811–37 and is entitled "Exterior Motion in the Restricted Problem of Three Bodies." It is followed, pp. 838–75, by W. D. MacMillan and W. Bartky, writing on "Permanent Configurations in the Problem of Four Bodies." This is concerned with such solutions as relate to the plane motion of the four bodies, moving with constant angular velocity about their centre of gravity; it contains diagrams and numerical tables. A short paper by Giulio Krall, "Mete lontane del moto di un sistema planetario" (*Atti Accad. naz. Lincei, Rend.*, VI, **15**, 664–9, 1932), continues some of the author's previous work, showing that his methods and the results of his theory hold also for the n-body problem.

Those who know J. L. Synge's work on the Geometry of Dynamics will be interested in his recent paper, "The Apsides of General Dynamical Systems" (*Trans. Amer. Math. Soc.*, **34**, 481–522, 1932). After first defining an apse for general dynamical systems, he simplifies some of Hadamard's general results by tensor analysis. Special results for the existence and location of min-max radial apsides are given; the theorems include interesting applications to the theory of small oscillations.

J. Proudman continues to write "On the dynamical theory of the tides.—IV. Flat seas of uniform depth" (*Proc. Lond. Math. Soc.*, II, **34**, 293–304, 1932). Previous parts of this paper derived an infinite set of equations of Lagrangian type, using an infinite sequence of parameters, functions of the time alone, to express the dynamical equations of the tides for a land-locked basin. The present Part IV treats the solution of these equations by approach from a finite number of equations and parameters. Its chief concern, as its title indicates, is with seas of uniform depth in which earth-curvature can be neglected.

Work on the top, further to that mentioned in my last article, has appeared from J. J. Corliss "On the Unsymmetric Top" (*Acta math.*, **59**, 423–41, 1932). It concerns a particular and hitherto unknown case of the unsymmetric top, where the solution is expressible in finite form. Naturally the solution holds only for certain ratios of the principal moments of inertia and for certain initial

conditions. It resembles degeneration of top-motion to spherical pendulum. Vector methods are employed by J. Krutkov, "Sur les équations du mouvement d'une toupie" (*Bull. Acad. Sci. U.R.S.S.*, VII, **4**, 489–502, 1932). The chief concern here is deriving a special form for the differential equation of the motion of the top. It is an extension of work that appears in the volume, "Allgemeine Theorie der Gyroskope und ihrer technischen Anwendungen," by J. Krutkov and A. N. Krylov.

Mention of the gyroscope recalls that Béghin studied the Sperry-Anschütz instrument, and concluded that there was a lack of generality in the formulation of the dynamical equations for a constrained system. The matter has now received attention from Antoni Przeborski in "Die allgemeinsten Gleichungen der klassischen Dynamik" (*Math. Z.*, **36**, 184–94, 1932). Previously there were Appell's equations; the ordinary Lagrangian equations for holonomic restraints; and the equations for smooth constraints, given by Amaldi and Levi-Civita. The present author gives the equations their most general form and makes comparison with the forms aforementioned.

ASTRONOMY. By R. W. Wrigley, M.A., Royal Observatory, Edinburgh.

Variation of Longitude.—It is now nearly fifty years since the existence of variation of latitude was definitely established by direct observation, but it was not possible to deal equally thoroughly with longitudes until the recent development of wireless telegraphy made it easy for stations distributed round the world to communicate with one another. Longitude variation was, however, strongly supported by Wegener, who advanced a theory of a progressive increase in the distance between the American and European continents of the order of one metre a year, and produced numerous geophysical, biological, geological and climatic arguments in support of his hypothesis, though he did not find it possible to account completely for all the forces necessary for the translation of the continents. But obviously the only method by which the reality of such movements can be accurately tested is the astronomical one, now reinforced by wireless signals. The older longitudes were fixed with the aid of the ordinary telegraph, and it was then imagined that they were correct to about 0·025 sec., equal to a distance of about 40 feet on the earth's equator. But in 1920 Professor R. A. Sampson drew attention to certain discrepancies in time determination at different observatories, which appeared when comparison was made by wireless signals. There were occasional anomalies in the time determinations of each

observatory when considered by itself, and there were also differences between the monthly mean for any single observatory when compared with the mean of all the others for the same month. The former discordances were ascribed by Sampson to erratic determinations of the instrumental errors, notably the level, but no satisfactory explanation was forthcoming for the others. In the *Report of the Astronomer Royal*, June 1933, a table is given showing the monthly means of the daily differences from Greenwich shown by the time signals sent from Paris, Nauen, Annapolis and Bordeaux during 1932. Taking a mean for the whole year, each of these stations was late on Greenwich, the figures being 0·008 sec., 0·020 sec., 0·039 sec., and 0·012 sec. respectively. But there is quite a different story if each month is taken by itself. The difference between Paris and Greenwich varies from − 0·034 sec. in January to + 0·057 sec. in August ; for Nauen it is − 0·020 sec. in February and + 0·054 sec. in July ; and Annapolis and Bordeaux show similar but slightly larger differences. Whatever may be the reason for these seasonal variations, it is at any rate obvious that former longitude determinations were much less accurate than was supposed, and it appears that if a series of such observations were spread out over a whole month and made under favourable conditions at the national observatories the results might still be 0·05 sec. or more in error. These figures point to a variation in longitude as a distinct possibility, accompanied maybe by fluctuations in the rotation of the earth as well as by actual movements in the earth's crust. The former was suggested some years ago by E. W. Brown (*Trans. Yale Astronomical Observatory*, vol. III), following on his discussion of irregularities in the apparent motion of the moon.

In the *Transactions of the International Astronomical Union*, vol. IV, reference is made to a series of world-wide longitude observations planned for October and November of this year. A similar but less comprehensive set of observations were carried through in 1926, and the same time of year has been selected in order to eliminate any seasonal variation. The programme is extensive—there are three principal circuits, the first comprising Greenwich, Tokio, Vancouver and Ottawa, the second Algiers, Zika-Wei and San Diego, and the third Cape Town, Adelaide, Wellington and Buenos Ayres, while nearly one hundred fixed observatories have agreed to take some share in the work. As far as possible all the observations will be made with small transit instruments fitted with impersonal moving micrometers, and the results will all be discussed and published by the Bureau International de l'Heure at Paris. It is hoped to secure definite confirmation of the existence of an error

of about one second in the longitudes of certain fundamental stations in South America which date from 1878–79, such an error being indicated by the observations of 1926.

In view of this international effort in the near future additional interest is attached to a paper by N. Stoyko in *Comptes Rendus*, Tome 194, No. 25, in which a comparison is made of the wireless time distributions from various observatories from 1920 to 1931, and evidence is found for a periodic change in the longitudes of the stations studied. These stations were arranged in groups, America (Washington), Continental Europe (Leningrad, Neuchatel, Paris, Potsdam, Poulkovo and Uccle), England (Greenwich), Japan (Tokio), and further divided into Eastern and Western Europe. Between these groups Stoyko finds certain displacements with a period of approximately eleven years and an amplitude varying between 0·03 sec. and 0·06 sec. From an examination of the various determinations of the longitude of Washington between 1866 and 1914 Stoyko considers that traces of a similar periodic change can be found in them, and he suggests a connection between this eleven-year period and that of sunspots, pointing out that the longitude variations could be accounted for either as pulsations of the earth regarded as an elastic body, or as alternate contractions and expansions of the crust alone. Whereas Wegener postulated a progressive increase in the distance of the American continent, Stoyko finds only a periodic displacement of amplitude 15 metres, the two continents drawing apart from 1920–25 and coming nearer to each other from 1925–30. But the evidence is far from conclusive, and further observations extending over several of the eleven-year periods will be necessary before definite proof of its existence is obtained. So many fruitless attempts have been made in the past to correlate various terrestrial phenomena with the sunspot period that further efforts are naturally viewed with a certain amount of scepticism. But undoubtedly perseverance in this line of research will eventually solve many problems regarding continental drift, pulsations of the earth, and contraction and expansion of its crust.

In *Monthly Notices, R.A.S.*, 1933, April, A. L. Loomis and H. T. Stetson call attention to an apparent lunar effect in time determination at Greenwich and Washington. The variations at the two observatories were compared with the moon's hour angle and declination for the dates in question, but, while it appeared that a lunar effect was present, the material was not sufficiently extensive to warrant definite statements as to its origin. Tidal effects in the earth's crust may be responsible for a displacement of the vertical and thus affect the time determinations, or a similar result might

be achieved by an actual tangential movement along the earth' surface. If the observed differences in the times between England and America are due to a relative shift in an east and west direction the actual displacement must be about 32 feet from the mean positions, but further study is necessary before any hypothesis of value can be formulated. It might be worth while to analyse the time determinations of each individual station with reference to lunar hour angle and declination in the hope of throwing some light on the anomalies experienced from time to time at every observatory. Indications of a lunar influence, depending on the moon's place in the sky, have also been found by Stetson from an analysis of small changes in observations of latitude made by Ross at Garthersburg (*Nature*, **123**, 127). An atmospheric tide with a consequent change in refraction is mentioned as another possible way by which these variations might be produced.

Various attempts which have been made in the past to correlate the sunspot period with atmospheric and other phenomena are recalled in *Communications to the National Academy of Sciences*, No. 112, by W S. Adams and S. B. Nicholson. By far the best established is the correlation with terrestrial magnetism, but there also seems to be an undoubted connection between sunspots and tropical temperatures compared in a series of observations fifty-eight years in length, a mean amplitude of 0·4° being found, with the maximum temperature at the minimum spot phase. Another probable correlation is that of ultra-violet radiation with sunspot frequency, though here observations are not sufficiently extended to give absolutely definite results. The relationship between sunspots and the measures of total solar radiation is still uncertain, and cannot be adequately described by simply stating that high radiation goes with the sunspot maximum, and vice versa. Although sun spots are cooler and faculæ hotter than the normal solar surface they are comparatively small in area, and important variations in the total solar radiation must have their origin in much larger portions of the sun's surface. It seems that spots, faculæ and prominences must be regarded merely as indications of some more fundamental solar activity. Changes in the transparency of either the sun's or the earth's atmosphere would readily affect the amount and quality of the transmitted solar radiation, but any such connection with sunspot activity has yet to be established. Investigation of these and kindred problems is proceeding at the Smithsonian and the Mount Wilson observatories, and it seems tolerably certain that various important connections between solar and terrestrial phenomena still remain to be discovered.

The Astrographic Chart.—International conferences are rather apt to be disappointing in their results, so it is not surprising that the astrographic chart and catalogue, the offspring of the first International Astronomical Congress, has failed in many ways to satisfy the high hopes which marked its inception. The suggestion that the whole sky should be divided up and mapped out by photography on a uniform plan was due to Gill, and, thanks largely to his energy and driving force, the Congress met in Paris in 1887. It was decided to take the photographs with identical instruments, giving a scale of 1 mm. to 1 minute of arc, and the work was to comprise a chart with stars to the 14th magnitude and a catalogue of reference stars down to magnitude 12. Each area had therefore to be photographed twice over with long and short exposures. Further, the initial photographs were intended to be only a first step in the great enterprise, and it was hoped to make repetitions at regular intervals and so secure a register of stellar proper motions over the whole sky.

The Congress was not uneventful and the North American observatories gave little support to the project, but the sky was finally divided among eighteen observatories and the members dispersed to commence their work. It was not long before it became apparent that the scheme had been too hastily conceived when astronomical photography was yet only in its infancy. With more experience a different instrument would have been chosen for the photographs, and it was not realised that the work would prove altogether too onerous and expensive for observatories of slender resources to undertake. On the average each share comprised the taking of some 1,200 plates, once for the chart and once for the catalogue, and for the latter about 500,000 stars had to be measured in duplicate and their magnitudes estimated. By 1900 three observatories had not even commenced their task, and further volunteers had to be called for then, and again in 1907, when one zone was still untouched. Now, thanks largely to the efforts of the late Professor H. H. Turner, the catalogue is at last approaching completion, and the bulk of the measures have been printed and circulated, while some observatories such as Sydney, Melbourne and Edinburgh have the measures in manuscript but lack the necessary funds for printing. Unfortunately the method of printing is far from uniform; the Greenwich measures are in rectangular co-ordinates given to four places of decimals, others like Oxford and Perth are content with three, while Catania and Helsingfors give in addition the Right Ascension and Declination of each star. This last is unquestionably the ideal way, for the reduction from rectangular to equatorial co-ordinates or vice versa is a somewhat

cumbrous performance for a single star, and limits considerably the usefulness of the catalogue. In fact, it seems as if each observatory will concentrate on work in connection with its own zone, and that the catalogue will be but little used by astronomers at large. Several zones have already been re-photographed for the investigation of proper motions. Greenwich Observatory has given forty years' work to its zone stretching from + 64° to the Pole, and the sixth volume of results has been issued this year. It and its predecessors contain the proper motions of 16,500 stars listed in the B.D. and of 13,500 fainter ones. As the stars selected for parallax observation are nearly all in this section of the sky it can be justly claimed that the general data available as to positions, magnitudes, proper motions and parallaxes are more complete in this zone than for any other region. The Cape zones were re-taken after an average time interval of twenty-five years, and these measures, whose reductions are now nearing completion, will give the proper motions of some 40,000 southern stars, a remarkable contribution to our knowledge of that hemisphere. The International Astronomical Union has shown a practical interest in the early completion of the whole catalogue by voting financial assistance for the printing, but naturally the funds at its disposal are limited.

The position of the chart is much less advanced, and it seems certain that it will never be finished and distributed in full. Only Greenwich and Algiers have actually completed their task, but San Fernando and the French observatories of Paris, Toulouse, and Bordeaux are now within sight of the end. The Potsdam zone has been undertaken by Uccle, and this observatory, Rome and Tacubaya have made a partial distribution, but others like Oxford, Perth and Hyderabad have not even given it a place in their programme. The southern sky has been almost entirely neglected; south of − 16° the only publications have been made by Cordoba in zone − 25°. There is also a lack of uniformity in the method of reproduction, and even in the length of exposure of the plates, Greenwich giving a single exposure of 40 minutes, Cordoba three of 20 minutes, and others three of 30 minutes, the images being grouped in a triangle. At the last meeting of the International Astronomical Union it was urged that the chart should be completed at least for the region of the sky containing the Milky Way.

PHYSICS. By L. F. BATES, D.Sc., Ph.D., F.Inst.P., University College, London.

THE APPROACH TO ABSOLUTE ZERO.—Until the last few weeks the lowest temperature ever recorded in the laboratory was 0·71° K.

This was attained by Keesom by the evaporation of liquid helium under reduced pressure, and represented the lowest limit which could reasonably be expected by such methods. Consequently, any further approach to absolute zero had to be made by an entirely different method.

Now this method has been available for many years. Workers in magnetism have long known it in the magneto-caloric effect. They have known, for example, that when a piece of ferromagnetic material is suddenly thrust into a very strong magnetic field an adiabatic rise of temperature of the substance results. Similarly, on sudden removal from the field an adiabatic fall of temperature occurs. These changes of temperature must not be associated with hysteresis phenomena which are irreversible, but with changes in the intrinsic magnetisation of the substance which are strictly reversible. By intrinsic magnetisation is meant the magnetisation of the individual microcrystals of the substance which exists even in the absence of an applied magnetic field, owing to the presence of a huge internal field in the substance itself. Since the internal field is so large, only very large external fields can produce appreciable changes in intrinsic magnetisation. The phenomena may be observed at all temperatures above and below the ferromagnetic Curie point. Indeed, a ferromagnetic substance has been chosen for discussion merely because it appears to be somewhat easier for the general reader to picture the phenomena in the case of a substance like iron. The phenomena can be observed with any paramagnetic substance, provided that sufficiently strong fields are used.

Now, when a paramagnetic substance is cooled to very low temperatures, we find that its magnetic properties become very pronounced, for, as a very rough approximation, we may consider the magnetic moment acquired in an external field to be inversely proportional to the absolute temperature. Consequently, magneto-caloric effects will be particularly pronounced at very low temperatures, and they may therefore be used to produce considerable adiabatic changes in temperature. It is by such means that the very low temperatures recorded by de Haas, Wiersma and Kramers (*Nature*, **131**, 719, 1933) have been attained, although full details of their work is not yet to hand.

De Haas, Wiersma and Kramers took a quantity of cerium fluoride and cooled it by means of liquid helium, a strong magnetic field being maintained in the space occupied by the fluoride. The substance was thus strongly magnetised and therefore possessed considerable negative potential energy. On suddenly removing the magnetic field the fluoride was adiabatically cooled to below 0·27° K.,

because heat was required to demagnetise the substance, to destroy the negative potential energy it possessed. The sudden cooling, of course, produced a further increase in the susceptibility of the substance, which was used to calculate the lowest temperature reached.

For, this temperature, 0·27° K., was not measured directly. It was determined by extrapolation from a susceptibility temperature graph previously determined over the range of liquid helium temperatures. Naturally, this extrapolation is open to error, and de Haas, Wiersma and Kramers therefore give 0·27 as an estimate which must undoubtedly be too high.

In like manner, Giauque and MacDougall (*Phys. Rev.*, **43**, 768, 1933) have made use of the adiabatic demagnetisation of gadolinium sulphate, $Gd_2(SO_4)_3 \cdot 8H_2O$, at temperatures of liquid helium. They produced a magnetic field of about 8,000 gauss by means of an iron-free solenoid, and used 61 gm. of the sulphate. They state that the lowest temperatures attained were measured by means of the inductance of a coil surrounding the gadolinium sulphate The coil was immersed in liquid helium and was isolated from the sulphate by an evacuated space. The measurement of its inductance gives, of course, a measure of the susceptibility of the sulphate.

Starting with the temperature of the sulphate at about 3·4° K., it was adiabatically cooled to 0·53° K.; starting from about 2° K. it was cooled to 0·34° K.; and, finally, starting from about 1·5° K. it was cooled to 0·25° K. It is therefore clear that the method will eventually permit of a still closer approach to absolute zero.

A Complete Analogy between Electrical and Mechanical Vibrations.—Teachers of physics will be very interested in a short article by C. Ramsauer (*Phys. Zeit.*, **34**, 459, 1933) on an example of complete analogy between electrical and mechanical vibrations. He takes as a basis of discussion the electrical vibrations which occur in a system consisting of two identical spherical conductors, each of capacity C, connected by a long straight wire at whose middle a coil of resistance R and self-inductance L is inserted.

If, initially, one sphere is charged with a quantity of electricity + Q and the other with − Q, so that their respective potentials are + E and − E, then it is easy to prove that the equation of motion of the system is

$$\frac{d^2E}{dt^2} + \left(\frac{R}{L}\right)\cdot\frac{dE}{dt} + \frac{2E}{L \cdot C} = 0.$$

If we compare this equation with the equation of motion of a pendulum in a viscous medium, we find no satisfactory mechanical analogue for the capacity C and no satisfactory electrical analogue

for the quantity $\frac{l}{g}$ which occurs in the pendulum equation. Again, if we compare it with the equation of motion of a column of liquid in a U-tube, we can find analogy between the resistance R and the viscosity of the liquid, and between L and the mass of the moving liquid, but the factor which must be regarded as the mechanical analogue of C is extremely complicated and difficult to interpret.

These difficulties disappear, however, if we compare the above electrical system with a system which consists of two identical hollow spheres of large internal volume V, connected by a pipe of negligible volume compared with V, and of cross-section 1 sq. cm. In the middle of the pipe is a small fan whose axis of rotation passes symmetrically along the tube and through the spheres. At each end of this axis is attached a bar of moment of inertia $\frac{I}{2}$. In the equilibrium state the new system contains air at atmospheric pressure.

If we suppose that initially one sphere contains an excess of air ΔA and is at a pressure ΔP above atmospheric while the other has a deficit ΔA and is at a pressure ΔP below atmospheric, air will move from the first sphere into the second, and thus cause the fan to rotate, so that energy is imparted to the inertia bars. After the pressures in the two spheres have become the same, the fan continues to rotate, and, in the absence of friction, will continue to do so until the pressure in the first sphere is ΔP below atmospheric, and that in the second is ΔP above atmospheric. The system has then completed half a vibration, and the process continues.

It is convenient to divide the air in the system into two equal volumes whose surface of separation at any instant is at a distance x from the centre of the pipe. It is also convenient to assume that the fan moves without slipping and that the velocity of a point on an inertia bar 1 cm. from the axis is equal to that of the air in the pipe. The equation of motion of the system can then be shown to be

$$\frac{d^2(\Delta P)}{dt^2} + \left(\frac{\eta}{I}\right)\cdot\frac{d(\Delta P)}{dt} + \frac{2\Delta P}{I\cdot V} = 0,$$

where η is the factor representing the effect of air resistance.

Comparing the two equations, we see that ΔP corresponds to E, ΔA corresponds to Q, V corresponds to C, I corresponds to L, and η corresponds to R. The analogy is complete.

THE PROBLEM OF PERMINVAR.—A perminvar is an alloy of iron, nickel and cobalt, which, through high temperature treatment and slow cooling, acquires certain very distinctive properties. For instance, the first portion of the initial curve of magnetic induction

with applied field is strictly linear,—the initial permeability is constant, hence the name perminvar. However, once the field has exceeded a certain value, permanent changes in the magnetic properties may occur and then the specimen can never be truly demagnetised. Again, many perminvars give hysteresis diagrams which exhibit very pronounced " waists "; others give diagrams which consist of a central portion, which is roughly rectangular, with " flares " or " satellites " extending from two of its corners.

A discussion of these features and their theoretical interpretation has been given by Auwers and Kühlewein (*Ann. der Phys.*, **5**, 107 and 121, 1933). In their first paper they give a general discussion of magnetic phenomena in so far as they are affected by the fields of neighbouring atoms and by peculiarities of superstructure. This discussion does not pretend to be complete, but it is very interesting and adequate for tackling the problem of perminvar.

In their second paper they start by considering a special model consisting of one magnet of large coercivity surrounded by a number of smaller magnetic needles, and then they examine the alignment which occurs in various applied fields. This model is later replaced by one in which a magnetic particle of large coercivity is associated with two particles of equal, but smaller, coercivity, and the coupling between the two kinds of particle is given a range of specified values. On this basis a series of hysteresis diagrams can be worked out and compared with those obtained in practice. The agreement in many cases is very striking.

Auwers and Kühlewein next proceed directly to identify the elementary particles of their theory with the atoms in a crystal lattice, and then to seek the relative distribution of the iron, cobalt and nickel atoms in the perminvar lattice by comparison with the known lattice of Heusler alloy. It is deduced that the permalloy lattice is simple cubic, face centred, in which the iron atoms form a simple cubic lattice whose side is equal to that of the iron γ lattice. The cobalt and nickel atoms then occupy the remaining positions indiscriminately, the ideal case corresponding to the structure $Fe(X)_3$, where X represents Co and, or, Ni in any proportions. The iron atoms correspond to those of lesser coercivity and the cobalt and nickel atoms to those of greater coercivity in the model outlined above.

This crystalline structure appears satisfactorily to explain all the strange phenomena so far observed with perminvar, including the phenomenon of constant initial permeability. It is rather interesting that the basic model used by Auwers and Kühlewein—without, of course, their extensions in the matter of superstructure—was origin-

ally used by S. W. J. Smith and J. Guild (*Proc. Phys. Soc.*, **24**, 342, 1912) and later elaborated (*Proc. Phys. Soc.*, **37**, 1, 1924) to explain the self-demagnetisation of annealed steel rods. Some surprising phenomena are described in the last two papers and some very suggestive experiments are described in the later one.

NOTE.—In the last issue of SCIENCE PROGRESS it was stated that prior to the work of Rao and Badami only the first three members of the Lyman series of hydrogen had been photographed. My attention has since been drawn to a much earlier paper by Hopfield (*Phys. Rev.* **35**, 1133, 1930) who photographed the first thirteen members.

METEOROLOGY. By E. V. NEWNHAM, B.Sc., Meteorological Office, London.

PAST RAINFALL OF CERTAIN PARTS OF ARIZONA AND NEW MEXICO DEDUCED FROM GROWTH RINGS OF LONG-LIVED TREES.—In SCIENCE PROGRESS for October 1932 a type of climate was discussed—the steppe climate—which has a little more rain than the desert climate and generally separates deserts from regions that receive abundant rainfall, either from the westerlies of the temperate zone or through forming part of the great rainy equatorial zone. There are examples of this climate, the general type of which is lettered BS in Köppen's system of classification, in hill country in Arizona and New Mexico, around latitude 35° N. The rather scanty rainfall is brought partly by occasional cyclonic rains or snowfalls in winter, and partly by rare convectional downpours in summer, often accompanied by thunder. It is the winter rain with its relatively low rate of "run-off" that is of most importance for vegetation. The character of the vegetation of the steppe climate is dependent upon a number of factors. In the regions under discussion the annual mean temperature is not very high, the soil is mostly porous, and the dry periods are often very long. In some parts only the huge *Sequoia gigantea* flourishes, with little or no scrub or woodland flora. The dry years, or successions of dry years, very much retard the growth of these coniferous trees, and leave abnormally narrow annual growth rings that can be seen on smoothed sections of the tree-trunks. Professor A. E. Douglass, of the University of Arizona, struck by the dependence of these trees upon rainfall to the virtual exclusion of other meteorological factors, has, since 1901, been working at the problem of estimating the rainfall of historic and prehistoric times from measurements of the annual growth rings. The problem is complicated by the fact that there is a variation of growth-rate with age of the tree, while insect pests act as a check on growth—a check

of varying efficacy according to the severity of the attack. Forest fires are also of great importance, for recovery from fire damage is sometimes very slow. Fortunately pests and fires tend to be more local than periods either of drought or of comparatively abundant rainfall; their disturbing effects can now, it is claimed, be almost completely allowed for.

It is difficult for anyone who has not been intimately associated with this work to form an accurate notion of the reliability of the method; the essential feature of "cross-identification" of rings of specially large or small thickness, in particular of certain striking sequences of thick and thin rings, may be strong evidence in support of the suitability of the particular species of tree selected for this method of study, but does not prove that the possible causes of fire present in the last hundred years are as numerous as were the causes present 2,000 or 3,000 years ago, nor does it prove that the pests of to-day are the same, or that they are on an average as destructive, as those of remote antiquity. These disturbing factors appear, in fact, susceptible to other than irregular local "chance" variation, and there is no obvious way of deciding how much they have altered generally over the entire area. This uncertainty, however, probably has little effect on that part of the work which deals with periodicities in rainfall of length not exceeding a few decades. Those interested in such periodicities will find many significant conclusions in the works referred to in the bibliography at the end of these notes. The following quotation from [7] in the bibliography will indicate the kind of result obtained: "The long Flagstaff (Arizona) record, from A.D. 1300 to A.D. 1925, perhaps the best in the three zones for rainfall history, gives cycles which check well with the solar record. From them we get a solar period of 11·30 years, lasting for 600 years, but with an interruption from A.D. 1630 to A.D. 1850; we get also a group of 7-, 14- and 21-year cycles beginning near A.D. 1660 and well established after A.D. 1700. The 21-year cycle has dominated Arizona tree-growth for 200 years. A 9·4-year cycle shows in the late 1700's, when the Sunspot cycle was of that length. The 7-year cycle was less active from 1880 to 1905 (in the Flagstaff area mean curve). Growth maxima occur at observed sunspot minima. . . .

"The dry years in the Flagstaff area tree-growth analyse best on 14- and 21-year cycles with major droughts at about 150-year intervals and minor droughts at 40- or 50-year intervals. The extension of the cycles observed in the last 200 years in the Flagstaff area indicates possible large growth of trees in the 1930's and 1950's, with depressions in the early and late 1940's."

The author concludes by saying that "It is recognised that much of the work is new and that time is needed to test and improve it, but it is hoped that these results are not greatly in error."

It may be noted that a fine specimen of one of the *Sequoia* sections can be seen at the Natural History Museum, South Kensington. Its indications extend back to the Roman occupation of Britain. Some of the oldest trees discovered since that section was made actually extend a thousand years B.C. The method has recently been used for the dating of prehistoric ruins in Pueblo, an area considerably nearer to equatorial America; this was made possible mainly through the discovery of a prehistoric beam at Showlow (about 50 miles south of Holbrook) on June 22, 1929, which showed well-known rings of the 1300's and certain drought rings of the late 1200's, and formed an indispensable connecting link between the records on very old beams and those on trees that lived into comparatively recent times.

BIBLIOGRAPHY

1. A. E. Douglass, 1919. *Climatic Cycles and Tree Growth.* Carnegie Inst., Wash., Pub. 289, vol. I.
2. A. E. Douglass, 1920. "Evidence of Climatic Effects in the Annual Rings of Trees," *Ecology*, vol. I, No. 1, January 1920, pp. 24–32.
3. A. E. Douglass, 1921. "Indication of Seasonal Variation of Weather in the Growth of Rings of Trees," *Journal Elect. and West. Industry*, **46**, May 15, 1921, 510.
4. A. E. Douglass, 1922. "Some Topographic and Climatic Characters in the Annual Rings of the Yellow Pines and Sequoias of the South-West," *Proc. Amer. Philo. Soc.*, vol. LXI, No. 2, April 1922, p. 117.
5. A. E. Douglass, 1922. "Some Aspects of the Use of the Annual Rings of Trees in Climatic Study," *Sci. Mon.*, **15**, 5, July 1922. Reprinted, *Smiths. Report*, 1922, Pub. 2731, 223–39.
6. A. E. Douglass, 1927. "Solar Records in Tree Growth," *Science*, vol. LXV, No. 1679, March 4, 1927, pp. 220–1.
7. A. E. Douglass, 1928. *Climatic Cycles and Tree Growth.* Carnegie Inst., Wash., Pub. 289, vol. II.
8. E. W. Maunder, 1921–22. "The Prolonged Sunspot Minimum, 1645–1715," *Jour. Brit. Ast. Assoc.*, **32**, No. 4, 1921–22, 140.
9. A. E. Douglass, 1931. "Tree Rings and Their Relation to Solar Variations and Chronology," *Annual Report Smiths. Inst.*, 1931.

BIOCHEMISTRY. By W. O. Kermack, M.A., D.Sc., Royal College of Physicians' Research Laboratory, Edinburgh.

Chemical Basis of Parasympathetic Function.—The elusive

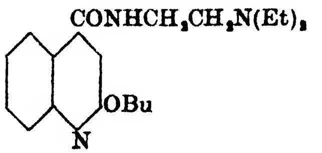
constitution has attracted many investigators and the interest which the subject has aroused depends, in part at least, on the realisation

of the greatly increased control over the animal and especially the human organism which a full solution of this problem would make possible ; but the laws and the mechanism which govern the relationship have so far proved to be very difficult of elucidation. Some simple rules may be formulated such as the statement that many esters of amino-alcohols, e.g. $RO{\cdot}COCH_2CH_2NH_2$ act as local anæsthetics, but, in contrast to this, percaine, a recently discovered local anæsthetic of very high activity (though of considerable toxicity) has the formula I and it seems difficult with our present knowledge to formulate a rational general theory of local anæsthetic action. It follows from the above that any investigation which explores and formulates in chemical terms the mechanism of the physiological and pharmacological action of chemical substances is worthy of serious attention, and it is therefore proposed to give some account of recent work on the parasympathetic action of physostigmine and of certain synthetic urethanes of similar pharmacological action, carried out chiefly by Loewi and his collaborators and by Stedman and Stedman.

It was shown some years ago by Loewi and Navratil (*Pflüger's Arch.*, **214**, 689) that the inhibiting action of the vagus on the frog's heart was not a direct nervous action on the muscle but that the stimulated vagus produced a chemical compound (probably acetyl choline (II)) and that this compound exerted a direct inhibiting effect on the heart muscle. Evidence was later brought to support the view that the action of the parasympathetic system in general operates through the local production of acetyl choline so that this chemical substance may be regarded as a kind of local hormone. In fact, acetyl choline bears a relation to the parasympathetic in many ways parallel to that which adrenaline bears to the sympathetic nervous system. The administration of physostigmine to an animal has results similar to those obtained by stimulating the parasympathetic and this effect was explained by Loewi in the following way. Loewi and his collaborators were able to prepare from frog's heart an extract which inactivated acetyl choline and it was later found that serum from most animals had the same inactivating effect. It was ultimately shown conclusively by Engelhart and Loewi (*Arch. exp. Path. Pharm.*, 1930, **150**, 1) and Mathes (*J. Physiol.*, 1930, **70**, 338) that this inactivation of acetyl choline was due to the presence in many animal tissues of an enzyme which hydrolysed the compound. It was further shown that this inactivation of acetyl choline by these extracts was inhibited by physostigmine, that is that physostigmine acted as an anti-enzyme and prevented the enzymic breakdown of acetyl choline. This

seems to offer an adequate explanation of the parasympathetic action of physostigmine, namely that the acetyl choline formed by the parasympathetic is no longer destroyed after physostigmine has been administered so that a small quantity of the highly active compound accumulates and produces its characteristic parasympathetic effects. Now it is to be observed that acetyl choline is really an ester, although of a somewhat special type, so that the enzyme which hydrolyses acetyl choline is presumably a type of esterase. It is therefore to be expected that esterases such as that responsible for the hydrolysis of methyl butyrate will also be inhibited by physostigmine. This was shown to be the case by Stedman and Stedman (*Biochem. J.*, 1931, **25**, 1166).

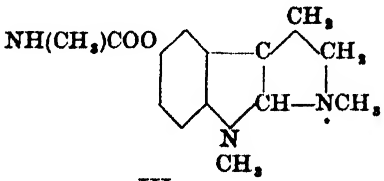
In 1925 the formula of physostigmine was finally elucidated by Stedman and Barger (*J. Chem. Soc.*, 1925, **127**, 247) and shown to



CH_2COOCH_3

$HO(CH_3)_2N{\cdot}CH_2$

II



III

be that represented by III. It will be seen that it contains the group RNHCOO characteristic of urethanes and it was natural that other urethanes should be tested in respect of their parasympathetic activity. A number of such urethanes were prepared by Stedman and Stedman (*J. Chem. Soc.*, 1929, **127**, 609). These authors found that compounds of the general type $RNHCOOC_6H_4R'$ where R is an alkyl group and R′ contains a basic amino group, have an activity closely resembling that of physostigmine. These compounds are conveniently tested by examining their miotic activity, that is the power to contract the pupil of the eye. The exact strength appears to depend on a number of factors such as degree of hydrolysis of their salts, ease of hydrolysis of the urethane group, power to permeate tissues (cf. Stedman, *Biochem. J.*, **23**, 17; *Amer. J. Physiol.*, 1929, **90**, 528). The most active of these compounds, namely, the

methylurethane of α-*m*-hydroxyphenylethyldimethylamine has for convenience been named miotine and its pharmacology has been worked out by Stedman and White (*J. Pharm. exp. Ther.*, 1931, **91**, 259). The action is qualitatively very closely parallel to that of physostigmine but quantitatively it is a little less strong.

In view of the close pharmacological resemblance of miotine and other synthetic urethanes to physostigmine it became of very great interest to inquire whether such compounds produced a similar action on esterases as they presumably should if the pharmacological action of physostigmine were really dependent on its behaviour as an anti-enzyme. It has now been shown by Stedman and Stedman (*Biochem. J.*, 1931, **25**, 1166; 1932, **26**, 1214) that, when methyl butyrate or tributyrin is used as a substrate, liver esterase and serum esterase are in fact inhibited by miotine and other synthetic urethanes. On the other hand, pancreatic lipase acting on methyl butyrate is inhibited but only by relatively large quantities of miotine whilst when this enzyme acts on tributyrin, miotine is without inhibiting effect. The urethanes are also without effect on serum phosphatase Matthes has also reported that miotine, like physostigmine, inhibits the hydrolysis of acetyl choline by the serum enzyme, though in this case the measurement was by pharmacological assay and not by direct chemical observation as is the case when methyl butyrate or tributyrin is used as substrate. As mentioned above, the active substances contain a urethane group and a basic group just as physostigmine does. Closely related compounds containing however only the urethane group or only the basic group are found to be devoid not only of pharmacological but also of enzyme-inhibiting activity. Furthermore, compounds which do not contain a benzene ring, such as a choline urethane, are inactive.

These results demonstrate clearly that the physiological activity of physostigmine is dependent on the presence of a urethane group and a basic group in conjunction with an aromatic nucleus. They also give strong support to the view of Loewi that the mechanism of their parasympathetic action is dependent on an inhibiting effect on the enzyme which hydrolyses acetyl choline with the subsequent accumulation of the latter highly active drug in the tissues. As pointed out by Stedman and Stedman, the fact that within the group of active urethanes the physiological action does not run parallel with the ester-inhibiting action is in no way inconsistent with the above view, for the two effects will be modified in different ways by special physical and chemical properties of the compounds such as adsorbability.

At the same time Stedman and White conclude that the possibility cannot be excluded that these physiologically active compounds may exert some influence on animal tissue independent of their effect on the hydrolysis of acetyl choline, but it appears unnecessary at present to assume that any such direct effect is more than only a relatively unimportant one. Space does not permit us here to enter into the many interesting points which arise in connection with the above work such as the question of the specificity of the enzymes concerned, whether for instance the esterase present in the liver which attacks methyl butyrate is identical with, related to, or quite different from the enzyme in the serum of various animals which hydrolyses acetyl choline.

Liver esterase preparations prepared in the ordinary way have no action on acetyl choline, nor have preparations from blood serum made in a similar way, that is by treatment with acetone followed by extraction with water. On the other hand, Stedman, Stedman and Easson (*Biochem. J.*, 1932, **26**, 2056) have shown in a recent paper that it is possible to prepare a relatively active and pure choline esterase from blood serum by following a technique which they have worked out. They leave open the question as to whether the serum choline esterase is identical with the ordinary serum esterase (which acts on methyl butyrate) but find that the relative activity of the preparations in respect of methyl butyrate esterase, choline esterase and lipase alters as purification proceeds. This indicates probably, though not certainly, that these enzymes are not identical, but it is always possible that inhibiting substances or accelerators in association with a single fundamental enzyme may be involved.

From the theoretical point of view, one of the most important problems which arise is to explain the mechanism of the enzyme inhibition of these esterases when very small quantities of the active urethanes are present. It should be emphasised that the concentrations involved are quite minute, for example, a liver esterase preparation of normal activity is inhibited by miotine in a concentration of 1/12,000,000, whilst for physostigmine the figure is of the same order of magnitude. Serum choline esterase is inhibited by physostigmine at a concentration of 1/40,000,000 (Loewi and Engelhart, *loc. cit.*). The first point which falls to be noticed is that the urethanes involve the group $C \cdot O \cdot C : O$ just as do the normal substrates of the enzymes, the esters. Now it is probable that when an enzyme acts on a substrate, some mechanism analogous to the fitting of a key into a lock, to use Emil Fischer's suggestion, is involved. This means that there is some arrangement present in the

esterase molecule which fits the group characteristic of the esters, that is the above-mentioned C · O · C : O. It follows that the esterase molecule will be able to fit the urethane group. Having done so it will nevertheless be unable to exercise its characteristic splitting activity, since the similarity between the urethane group and the ester group is only partial and further since the urethanes do not normally hydrolyse but undergo fission according to the equation RNHCOOR′ = RNCO + HOR′ But the esterase molecules, although unable to act on the urethane, will be inactivated by the latter in virtue of the characteristic grouping being occupied. As mentioned above, only aromatic urethanes with a basic side-chain possess the property of inactivating esterase. The basic side-chain may facilitate the approach of the esterase to the urethane molecule and so make the blocking process possible.

Whilst acetyl choline is being discussed reference may be made to a new method elaborated by Minz (*Arch. exp. Path. Pharm.*, 1932, **167**, 85) for the physiological detection of acetyl choline in very minute concentration. The technique depends on the fact that a preparation of the back muscles of the leech becomes very sensitive to the action of acetyl choline after sensitisation with physostigmine. To other substances likely to be present in tissue extracts, etc., suspected of containing acetyl choline, this preparation is almost completely insensitive. By the same technique Dressler, Kwialkowski and Schiff (*Arch. exp. Path. Pharm.*, 1933, **170**, 428) have shown that the blood pressure lowering substance present in certain extracts of mistletoe, and used therapeutically, is probably choline. In this case the leech preparation is acted upon by the extract after but not before acetylation. One other interesting development may be mentioned. It has been shown above that enzymes have been discovered in the tissues and plasma which destroy acetyl choline, so that if a substance could be found of the same general type but resistant to the action of choline esterase, it might be expected to be of considerably higher biological activity. Such a substance, it is claimed (Kreitman, *Arch. exp. Path. Pharm.*, 1932, **164**, 346), is found in the urethane $NH_2COOCH_2CH_2N(CH_3)_3OH$ which is said to have several times the activity of acetyl choline. It would be in accordance with the considerations advanced in the preceding paragraphs that a compound of this type should resist hydrolysis by choline esterase.

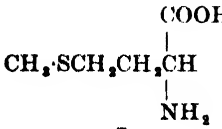
New Amino Acids.—The number of naturally occurring amino acids, those fundamental structural units from which proteins are essentially built up, is gradually increasing. It is now a number of years since methionine (I) was isolated from casein by Mueller and

its constitution has since been established by several independent syntheses (Barger and Coyne, *Biochem. J.*, 1928, **22**, 1417. Windaus and Marvel, *J. Amer. Chem. Soc.*, 1930, **52**, 2575. Barger and Weichselbaum, *Biochem. J.*, 1931, **25**, 997). In 1929, ergothioneine was recognised in the blood of pigs by Hunter and Eagles as partly responsible for its reducing power. It had previously been discovered in ergot of rye by Tanret (*J. Pharm. Chim.*, 1909 (VI), 145) and shown by Barger and Ewins (*J. Chem. Soc*, 1911, **99**, 2336) to be the betaine (II) of thiolhistidine. Strenuous attempts have been made in recent years to effect its synthesis but so far these have proved unsuccessful in consequence of the technical difficulties encountered (cf. Ashley and Harington, *J. Chem. Soc.*, 1930, 2586, and Harington and Overhof, *Biochem. J.*, 1933, **27**, 338). Carnosine and anserine are two dipeptides which are met with in muscles of various animals (Ackermann and Hoppe Seyler, *Z. Physiol. Chem.*, 1931, **197**, 135; Wolff and Wilson, *J. Biol. Chem.*, 1932, **95**, 495) and as they are respectively composed of β-alanyl histidine and β-alanyl methyl histidine they furnish examples of the occurrence of two of the less well known amino acids, namely β-alanine ($NH_2CH_2CH_2COOH$) and methyl histidine.

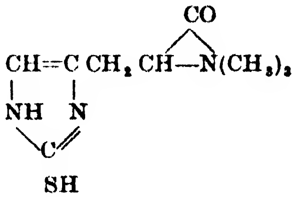
Another new amino acid which has created considerable interest within the last year or two is one which was isolated by Koga and Odake in 1914 from the juice of the water-melon (*Citrullus vulgaris*) (*J. Tokyo Chem. Soc.*, 1914, **35**, 519). Little attention appears to have been paid to it until 1930, when Wada (*Proc. Imp. Acad. Tokyo*, 1930, **6**, 15; see also *Biochem. Z.*, 1930, **224**, 420) again isolated this amino acid, to which the name citrulline has been given, from the juice of the water-melon and established its constitution by synthesis as α-amino-δ-carbamidovaleric acid (III). Its formula may be compared with that of arginine (IV). It will be seen that the only difference is that the NH group in IV is replaced by $=O$ in III. Interest in citrulline has recently been increased since Wada (*Biochem. Z.*, 1933, **257**, 1) discovered that it is a constituent of ordinary commercial casein from milk. From the products of the tryptic hydrolysis of casein in neutral solution citrulline was isolated and identified. Arginine under these conditions does not yield citrulline, so that in all probability citrulline is one of the constituent amino acids of casein and therefore probably of other proteins as well. It is however not surprising that it escaped isolation for so long, as in presence of alkali it is converted into ornithine (V), whilst in presence of acid it yields proline (VI). In consequence, it cannot be obtained from the hydrolysis products of proteins by acids or alkalis. The addition even of 0·2 per cent. sodium carbonate

to the tryptic digest of casein reduced the yield to zero and increased that of ornithine.

In the course of his work on the hydrolysis of casein and the isolation of citrulline Wada obtained evidence of the presence of another new amino acid (*Biochem. Z.*, 1933, **262**, 68). This he has now isolated in pure form and finds that it possesses the formula $C_6H_{12}O_4N_2$ m.p. 222° with decomposition. A close investigation of its properties and its decomposition products has led him to assign to it the structural formula (VII) It gives lysine (VIII) on hydrolysis with alkali and has therefore been named prolysine. It gives the Schiff and Ehrlich colour reactions and in consequence



I.



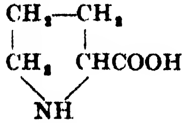
II.

III. $NH_2{\cdot}CO{\cdot}NH{\cdot}CH_2{\cdot}CH_2{\cdot}CH_2{\cdot}CH(NH_2)\,COOH$.

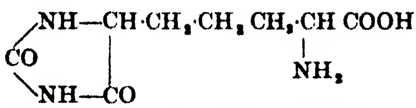
IV. $NH_2C(:NH)\,NH{\cdot}CH_2\,CH_2\,CH_2CH(NH_2){\cdot}COOH$.

V. $NH_2{\cdot}CH_2\,CH_2{\cdot}CH_2{\cdot}CH(NH_2){\cdot}COOH$.

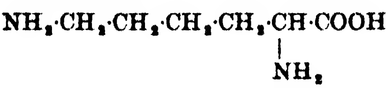
VI.



VII.



VIII.



of its being a derivative of urea it forms a well-defined crystalline compound with xanthydrol. This latter compound indeed affords a ready method of separating prolysine from the hydrolysis products of protein. It is more stable to acids than is citrulline but is decomposed by alkali. It is present in considerable quantities in the products of the hydrolysis of casein and gelatine by acids. From 480 g. of casein Wada isolated 6·7 g. of the silver salt, whilst from 500 g. of gelatine the yield was 22 g. of silver salt. It appears from these figures that prolysine may constitute a not insignificant part of the protein molecule and as it is an amino acid of rather a novel type its isolation may be regarded as a distinct advance in a fundamental domain of biochemistry.

Synthesis of Urea.—The isolation by Wada of citrulline from casein, which has been mentioned above, makes it probable that citrulline is an important amino acid and takes part in the metabolism of living cells. This conjecture is supported by the very interesting work of Krebs and Henseleit (*Zeit. physiol. Chem.*, 1932, **210**, 33) on the synthesis of urea from ammonia by animal tissues. These authors examined the rate of formation of urea by thin sections of tissues suspended in solution containing an ammonium salt. Liver tissue from well-fed animals was found to be highly active whilst that from fasting animals was much less so. Conjecturing that the difference was due to a deficiency in the case of the fasting animals of some relatively simple metabolite, the authors examined the stimulative effect on urea formation of a large number of simple substances. Whilst a small effect was observed with certain non-nitrogenous substances such as glucose, fructose or lactate, the effect of small quantities of ornithine was of quite a different order and moreover was apparently truly catalytic, that is, under the best conditions (which included the presence in the solution of a small amount of lactate) 1 molecule of ornithine brought about the formation of 7 to 13 molecules of urea. Approximately 2 molecules of ammonia disappeared for each molecule of urea formed. Krebs and Henseleit suggest the following scheme to explain these results.

$$\begin{array}{ll}
NH_2[CH_2]_3 \cdot CH \cdot (NH_2)COOH + NH_3 + CO_2 & \text{ornithine} \\
\downarrow & \downarrow \\
NH_2CONH \cdot [CH_2]_3CH(NH_2)COOH + H_2O + NH_3 & \text{citrulline} \\
\downarrow & \downarrow \\
NH_2 \cdot C(.NH) \cdot NH[CH_2]_3 \cdot CH(NH_2)COOH + H_2O & \text{arginine} \\
\downarrow & \downarrow \\
NH_2[CH_2]_3 \cdot CH(NH_2)COOH \cdot + CO(NH_2)_2 & \text{ornithine + urea}
\end{array}$$

The last stage, the hydrolysis of arginine to ornithine and urea, is presumably effected by the enzyme arginase known to be present in liver tissue. In accordance with this theory it is found that the production of urea is likewise increased by the addition of citrulline but the difficulty arises that in this case the action does not appear to be truly catalytic. A little more than one molecule of ammonia is used up for each molecule of urea formed; the other nitrogen atom coming apparently from the citrulline which is used up in the process. Now one would have expected that under favourable conditions both arginine and citrulline would have been just as active catalytically as ornithine, whereas the authors make it clear that they do not consider that citrulline behaves catalytically and they say very little about arginine. At the same time the theory which they have formulated is a very attractive one and it may be expected that the difficulty just referred to will be explained when the work is further developed.

GEOLOGY. By G. W. Tyrrell, A.R.C.Sc., D.Sc., The University, Glasgow.

Stratigraphy and Regional Geology.—Sir T. H. Holland's Presidential Address to the Geological Society on "The Geological Age of the Glacial Horizon at the Base of the Gondwana System" (*Quart. Journ. Geol. Soc.*, vol. LXXXIX, 1933, *Proc.*, pp. lxiv–lxxxvi) is an illuminating discussion of a great problem in which British workers are at variance with American and German investigators. The former regard the Gondwana glacial horizon as near the Carboniferous-Permian boundary with a distinct leaning towards the older period; the German and American authorities, with Professor C. Schuchert as protagonist, insist on a Middle Permian date, or at most late Lower Permian, as the oldest possible. Sir T. H. Holland quotes a mass of evidence from the work of the Geological Survey of India to show that the Talchir in India, as also the Lochinvar in Australia (David and Süssmilch), and the glacial horizon in the Argentine (du Toit), must be placed well below the boundary line between the Permian and the Carboniferous.

The work of Sir T. W. E. David and C. A. Süssmilch on "Upper Palæozoic Glaciations of Australia" (*Bull. Geol. Soc. Amer.*, **42**, 1931, 481–522) has yielded the following conclusions. "The Upper Palæozoic glaciation of Australia was not confined to a limited period of geological time, such as the Middle Permian, as claimed by Schuchert, but had its beginnings in the Kuttung epoch (Kulm), and continued to the top of the Lower Permian epoch (Upper Marine epoch), when it finally disappeared. In the strata deposited during this time in eastern Australia there occur five distinct glacial horizons. Each of these horizons gives evidence of an epoch of pronounced (although not necessarily equally intense) glacial conditions, probably separated from one another by periods of a milder climate. In the case of glacial horizons four and five, there intervened a period during which an important series of coal-measures were deposited."

In his critical review of the above memoir, Professor C. Schuchert (*Amer. Journ. Sci.*, vol. XXIII, 1932, pp. 540–8) accepts the Kuttung glaciation as of Kulm age, but believes that it was separated from the Lochinvar glaciation by the whole of Upper Carboniferous time. He regards the Lochinvar as the equivalent of the Talchir and Dwyka tillites, and as late Lower Permian or early Middle Permian age.

A valuable "Brief Review of the Dwyka Glaciation of South Africa" is contributed by Dr. A. L. du Toit (*C.R. XV. Internat.*

Geol. Congr. South Africa, 1929, vol. II, pp. 90–102) in which he shows that the Permo-Carboniferous ice-sheets radiated from three main and from one minor centre, of which the oldest lay in the west, the youngest in the east. Advances and retreats of the ice are indicated by breaks in the mass of tillites and by boulder-pavements, although the evidence is insufficient to decide on the former existence of true interglacial periods. With regard to the age of the glacial horizons du Toit states: "It is hence clear that the lengthy refrigeration of the Southern Hemisphere started just before the close of the Lower Carboniferous and that the main phases terminated before the end of the Upper Carboniferous."

Professor C. Schuchert attacks the Gondwana problem from the palæo-botanical point of view in his paper entitled "Permian Floral Provinces and Their Interrelations" (*Amer. Journ. Sci.*, vol. XXIV, 1932, pp. 405–13) which is a discussion of Gothan's recent papers (W. Gothan, "Die pflanzengeographischen Verhältnisse am Ende des Paläozoikums," *Engler's Bot. Jahrb.*, **63**, 1930, 350–67; "Der Wert der karbonischen und permischen Flora als Leitfossilien," *Pal. Zeit.*, **13**, 1931, 298–309) with some notes by Dr. D. White. Gothan's main conclusion is that distinct floral provinces appeared for the first time in geological history in the late Carboniferous, and especially in the early Permian, when there was a northern or Rotliegende flora, and a southern or Glossopteris flora. Gothan disagrees with Seward in assigning the earliest appearance of the Glossopteris flora in Australia to the Upper Carboniferous, and he dissents from Schuchert's former view (1928) that the late-Palæozoic ice age occurred in the Middle Permian. On the evidence of the Salt Range (India) fusulinids and other data Schuchert now places the Talchir tillites in the early Permian, but not in the "basal" Permian.

A. W. Grabau's monumental memoir on "The Permian of Mongolia" (*Amer. Mus. Nat. Hist. Publ.*, "Natural History of Central Asia," vol. IV, 1931, xliii + 665 pp.) contains much material relevant to the foregoing controversy. It is reviewed by C. Schuchert (*Amer. Journ. Sci.*, vol. XXII, 1931, pp. 373–5), and by R. L. Sherlock (*Geol. Mag.*, vol. LXVIII, 1931, pp. 334–5).

A very important memoir on "The Geology of Gondwanaland" by C. S. Fox (*Mem. Geol. Surv. India*, **58**, 1931, 241 pp.) provides a summary of all available information respecting the Gondwana System of India. This formation, which covers the time interval between Upper Carboniferous and Lower Cretaceous, traverses the accepted division between Palæozoic and Mesozoic. A short review of this work is to be found in *Nature*, Oct. 31, 1931, p. 763.

The Jharia Coalfield, described by C. S. Fox (*Mem. Geol. Surv. India*, **56**, 1930, 255 pp.), is a part of the Gondwana coal-bearing area of India. The coalfield has been let down and preserved by folding and faulting within a basement of Archæan gneiss.

In his note entitled " How the Kimberlite Pipes serve to Reveal the Unknown " Dr. A. L. du Toit (*Econ. Geol.*, vol. XXVII, 1932, pp. 206–10) shows how " descended inclusions " in the diamondiferous pipes serve stratigraphical ends in proving the former extent of the Karroo formations. Thus the Karroo sediments must formerly have extended over a vast area to the west of Kimberley, and the Stormberg basalts must have reached in the past 250 miles farther north-west than their present limits in Basutoland.

L. Reinecke discusses the character, succession, and origin of the Witwatersrand System of South Africa (*Trans. Geol. Soc. S. Afr.*, **33**, 1931, 111–33) He states that it differs from all known marine systems, and that " the evidence of its having been deposited by streams on the lower piedmont slopes and floodplains of a large river system appears to be quite conclusive "

The geology of the country around Que Que, Gwelo District, Southern Rhodesia, which contains the great Phœnix and Gaika gold mines, has been described by A. M. Macgregor (*Southern Rhodesia : Geol. Surv. Bull.*, No. 20, 1932, 113 pp.). The oldest rocks are serpentines, talc-schists, and magnesite-rocks which constitute a Magnesian Series. Into this a gneissic granite is intruded. With intervening unconformities there follow two series of pillow lavas, with jaspilite, banded ironstones, and felsites, and two sedimentary series. A number of intrusive dolerites, keratophyres, lamprophyres, etc., cut the above complex. The granites of the region are notable in containing relatively large amounts of strontia.

Another Rhodesian mining region has been described by A. E. Phaup in his memoir on " The Geology of the Antelope Gold Belt " (*Southern Rhodesia : Geol. Surv. Bull.*, No. 21, 1932, 119 pp.). This region is one of the minor strips of crystalline schists emplaced between masses of granite. Greenstones, banded ironstones and serpentines are present among the schists. The gold is found in serpentine which has been altered to actinolite-schist.

The geology of the N'Changa District of Northern Rhodesia has been dealt with by G. C. A. Jackson (*Quart. Journ. Geol. Soc.*, vol. LXXXVIII, 1932, pp. 443–515). The region is underlain by four principal series of metamorphic sediments of probable Archæan and Pre-Cambrian (or possibly early Palæozoic) ages. These have been intruded by early and late batholiths of granite, and last of all,

by sill-like masses of scapolitised and uralitised gabbros and norites. All the rocks have suffered dynamothermal metamorphism of low grade, and in the older series recrystallisation is almost complete. The shaly and arkosic members of the Bwana M'Kubwa Series contain the enormous replacement copper deposits of Northern Rhodesia, the mineralisation of which is believed to be connected with the intrusion of the younger granites. Dr. Jackson gives an outline of the geological history of the N'Changa District in a later paper (*Geol. Mag.*, vol. LXX, 1933, pp. 49–57).

The Sub-Commission of African Surveys appointed by the International Geological Congress has just issued the Proceedings of its first meeting (*Proc. of First Meeting of African Geol. Surveys*, South Equatorial Section, held at Kigoma, July, 1931 ; *Internat. Geol. Congr.*, *Sub-Comm. of African Surveys* ; Louvain, *Inst. Geol. de l'Univ.*, 1932, 31 pp. and geol. map). The chief result is the production of a beautiful colour-printed geological map of Southern Equatorial Africa on the scale of 1 : 5,000,000. Valuable discussions on Pre-Katanga, Katanga, Karroo, and post-Karroo formations, and on Pre-Rift and Rift tectonics, are reported.

An excellent companion to the above is the new Provisional Geological Map of Tanganyika with Explanatory Notes, by E. O. Teale (*Tanganyika Territory, Geol. Surv. Dept. Bull.*, No. 6, 1933, 32 pp.). The map is on the scale of 1 : 2,000,000 and is finely colour-printed. The accompanying notes form a convenient summary of the geology of Tanganyika.

The Ruhuhu Coalfields in Tanganyika Territory, described by G. M. Stockley (*Quart. Journ. Geol. Soc.*, vol. LXXXVIII, 1932, pp. 610–22), are of Karroo (Ecca) age. The rocks are faulted to north and south against primitive gneisses, and are themselves divided into a series of fault blocks, the faults dating from the period of rift-valley formation. The Karroo succession in this region is the most complete yet described from East Africa.

The metamorphic phenomena described by H. A. Stheeman in his memoir on " The Geology of South-western Uganda " (The Hague : M. Nijhoff, 1932, 144 pp.) have been previously mentioned (SCIENCE PROGRESS, July 1933, p. 125). The memoir is also an important contribution to the regional geology of Central Africa, as it deals exhaustively with the morphology, stratigraphy, and tectonics of a large part of Uganda.

On the basis of age-determinations of the Oldoway fauna and culture Dr. H. Reck (" Über das Alter der ostafrikanischen Gräben und Bruchstufen," *Festschr. f. Carl Uhlig*, 1932, pp. 65–75) comes to the conclusion that the age of the main fracture-phase of the East

African rift valleys must be placed in the Middle Pleistocene, which is a much later date than that assigned by former workers.

In his work on "The Geology of North-Eastern British Somaliland" C. B. Brown (*Quart. Journ. Geol. Soc.*, vol. LXXXVII, 1931, pp. 259–80) shows that a stratigraphical column nearly 6,000 feet in thickness consists of Palæozoic (?), Jurassic, Cretaceous, Eocene, Oligocene, and Miocene, Pleistocene and Recent rocks. The Mesozoic and Kainozoic strata rest on older rocks possibly of Palæozoic age, and the whole mass has been uplifted several thousands of feet along the south of the Gulf of Aden. The seaward blocks have subsided as part of a branch of the African Rift-system.

The Obuasi Goldfield (Gold Coast), the geology of which has been described by Dr. N. R. Junner (*Gold Coast Geol. Surv. Mem.*, No. 2, 1932, 43 pp., 22 plates), consists of a probably Pre-Cambrian series of phyllites, greywackes, conglomerates, quartzites, and grits, which contains lavas of basaltic composition, and has been intruded first by soda-granites, and later by gabbros, norites, and diabases which have suffered much alteration. Dolerite dikes represent the latest igneous rocks.

According to R. Pfalz (*Geol. Rundsch.*, vol. XXIII, 1932, pp. 122–32) a section across Cyrenaica from south to north shows Palæozoic marginal ranges followed by Nubian Sandstone, here probably older than the Lower Cretaceous. After a block of Archæan comes to the north a concordant series of Lower Cretaceous Nubian Sandstone, Upper Cretaceous, and Eocene, which in distribution and ages renders probable a connection with the Egyptian occurrences. The succession closes with a Miocene transgression in which Langhian and Helvetian sediments were deposited.

In a paper on "The Geology of Jebel Usdum, Dead Sea," B. K. N. Wyllie (*Geol. Mag.*, vol. LXVIII, 1931, pp. 366–72) shows that the salt deposits of this locality are not products of the Pleistocene Dead Sea, nor of its predecessor, but have reached their present position by intrusive processes, their source lying in the Mesozoic or possibly in Palæozoic formations.

The geology of the Vizagapatam Harbour area is described by C. Mahadevan (*Q.J. Geol., Min. and Metall. Soc. India*, vol. II, No. 4, 1929, pp. 165–79). The rocks consist of Archæan garnetiferous gneisses, into which are intruded granites, charnockites, and "kodurites" in the order given. In the last-named series local concentrations of manganese minerals are common.

As the writer has not seen H. de Terra's important memoir "Geologische Forschungen im westlichen K'Un Lun und Karakorum Himalaya" (*Wiss. Ergebn. d. Dr. Trinkler'schen Zentralasien*

Exped., vol. II, 1932, 196 pp.) he transcribes a paragraph from Professor C. R. Longwell's review (*Amer. Journ. Sci.*, vol. XXV, 1933, pp. 185–6). "De Terra reports that the prominent trend lines have a general direction ranging from N.W. to W., but several episodes of deformation are represented, the first of which occurred in Pre-Cambrian time. The K'Un Lun region was folded in the late Palæozoic, and formed part of the land mass N. of the Tethyan sea which covered the Karakorum-Himalayan area in the Mesozoic era. Intense folding affected the latter area at the close of the Cretaceous period. In the Karakorum the folds are strongly overturned to the north, and the folded rocks are thrust northward against the older rocks of the K'Un Lun. Tertiary continental deposits were laid down locally across the eroded folds, and these youngest strata have in turn been deformed by a comparatively weak disturbance."

In a valuable memoir full of detail Professor D. N. Wadia exhaustively discusses "The Syntaxis of the North-west Himalaya: Its Rocks, Tectonics, and Orogeny" (*Rec. Geol. Surv. India*, vol. LXV, Pt. 2, 1931, pp. 189–220). In a further paper Professor Wadia deals with the geology of Nanga Parbat (26,620 feet), the culminating peak of the North-west Himalaya (*ibid.*, vol. LXVI, 1932, pp. 212–34). The mountain consists mainly of biotite-gneiss intruded by granites, with a Pre-Cambrian series (Salkhala Ser.) of metamorphic sediments to the South. A zone of intimate admixture, with increasing metamorphism towards the gneiss, intervenes between the Salkhala Series and the Nanga Parbat biotite-gneiss. Immense basic intrusions formed the latest injections into the region.

In his paper on "The Tertiary Geosyncline of North-west Punjab and the History of Quaternary Earth-movements and Drainage of the Gangetic Trough," Professor D. N. Wadia (*Q.J. Geol., Min. and Metall. Soc. of India*, vol. IV, No. 3, 1932, pp. 69–96) shows that the north Indian trough represents the sagging of a Foreland mass in front of the wider and deeper Himalayan geosyncline. The region described is part of a greater synclinorium submerged beneath the Indo-Gangetic alluvium, which separates the Peninsular horst from the Himalayan orogen.

In a review of recent contributions to the geology of the northern border of Asia, H. G. Backlund (*Geol. Rundsch.*, vol. XXIII, 1932, pp. 13–23) includes a valuable summary of the geological results of N. Urwantzew's recent expedition to the Taimyr Peninsula of Siberia (*Trans. Geol. and Prospecting Service of U.S.S.R. Geol. Surv. Sect. of East Asia*, No. 65, 1931). Another work on the geology of northern Siberia (B. N. Rozkov, "Norilsk and Severna Districts,

N.W. part of Yenesei-Lena Platform," *Bull. Soc. Nat. Moscow. Sect. geol.*, **10** (2), 1932, 268–94) is reviewed in *Nature*, July 29, 1933, p. 176.

H. Frebold (" Geologische Ergebnisse und Aufgaben der Arktisforschung," *Geol. Rundsch.*, vol. XXII, 1931, pp 29–40) has written a useful summary of recent contributions to Arctic geology.

Dr. Frebold has continued his work on Spitsbergen geology (see Science Progress, Jan. 1931, p. 404) with an exhaustive memoir on " Verbreitung und Ausbildung des Mesozoikums in Spitzbergen " (*Norges Svalbard- og Ishavs-Undersökelser. Skr. Svalbard og Ishavet*, No. 31, 1930, 126 pp.), which is illustrated by excellent palæogeographical maps showing the varying distribution of land and sea in north polar regions during Mesozoic times.

In a further memoir entitled " Fazielle Verhältnisse des Mesozoikums in Eisfjordgebiet Spitzbergens : Ein Beitrag zur Entwicklunggeschichte des Skandiks " (*ibid.*, No. 37, 1931, 94 pp.), Dr. Frebold shows that the so-called " Permian " strata comprising the Myalina Beds, Pseudomonotis Beds, Hustedia Limestone, and equivalent formations, can now be assigned without hesitation to the lowermost Trias. The facies-relations of the Mesozoic in the Ice Fjord region cannot be otherwise interpreted than by the presence of a land area west of the present site of Spitsbergen, a land which may either have been a much more extensive range than the present Caledonian mountains of Spitsbergen, or may have been a " borderland " in Schuchert's sense.

A very large amount of stratigraphical work on Greenland has recently been published by Danish and German workers. The main titles are listed below : L. Koch, " Carboniferous and Triassic Stratigraphy of East Greenland," *Medd. Grönland*, Bd. 83, No. 2, 1931, 99 pp. H. Frebold, " Fauna, stratigraphische und paläogeographische Verhältnisse des ostgrönländischen Zechsteins," *ibid.*, Bd. 84, No. 1, 1931, 55 pp. H. Frebold, " Das marine Oberkarbon Ostgrönlands," *ibid.*, No. 2, 1931, 88 pp. H. Frebold, " Unterer mariner Zechstein in Ostgrönland und das Alter der Depot Island Formation," *ibid.*, No. 3, 1931, 38 pp. H. Frebold, " Grundzüge der tektonischen Entwicklung Ostgrönlands in postdevonischer Zeit," *ibid.*, Bd. 94, No. 2, 1932, 112 pp. A. Noe-Nygaard and G. Save-Söderbergh, " Zur Stratigraphie der Nordöstecke der Claveringinsel (Ostgrönland)," *ibid.*, No. 3, 1932, 29 pp. D. Malmquist, " Zur Kenntnis des oberkarbonischen Sedimente der westlichen Clavering Insel, Ostgrönland," *ibid.*, No. 6, 1932.

A. K. Orvin has described an interesting fossil river bed in East Greenland, containing trunks and numerous fragments of fossil

wood enclosed between two flows of Tertiary basalt lava (*Norges Svalbard- og Ishavs-Undersökelser. Medd.*, Nr. 14, 1932, pp. 469–74). The age of the valley is fixed as approximately Eocene from the evidence of the wood, and of other Tertiary sediments.

The geological work of the Cambridge Expedition to East Greenland in 1929, expounded by M. M. L. Parkinson and W. F. Whittard (*Quart. Journ. Geol. Soc.*, vol. LXXXVII, 1931, pp. 650–74), makes it impossible, in the authors' view, to accept Backlund's conclusion (see SCIENCE PROGRESS, April 1933, p. 588) that the metamorphic complexes of East Greenland are of Caledonian age. The triple repetition of belts of sedimentary and metamorphic rocks trending in a N.-S. direction is explained by imbrication on a grand scale, successive wedges of these rocks having advanced towards the west impelled by pressures from the east. The intrusion of the Caledonian granites in regions of structural weakness was the igneous accompaniment of these movements. Magnificent photographs of tectonic structures illustrate this important paper.

In two recent papers Professor O. Wilckens ("Der Bogen der Südlichen Antillen (Antarktis)," *Sitz.-ber. d. Niederrhein. Ges. f. Natur.- u. Heilkunde z. Bonn* (*Naturw. Abt.*), 1932, pp. 3–14; "Fossilien und Gesteine von Süd-Georgien," *Sci. Results Norweg. Antarct. Exped.* 1927–28 *and* 1928–29, No. 8, *Norske Vidensk.-Akad. Oslo*, 1932, 28 pp.) concludes that the arc of the "Southern Antilles" is an established fact. The Patagonian Cordillera, South Georgia, the Clerke Rocks, South Sandwich Islands, South Orkneys, South Shetlands, and Grahamland, have uniform structures of highly-folded Mesozoic rocks, with Andean plutonics, and Tertiary or younger igneous rocks. While these various groups do not occur everywhere throughout the arc, the evidences of accordance of structures are so clear that the relegation of all to a single tectonic unit is unavoidable.

In a discussion of the problem of the Scotia Arc (to use the more convenient designation introduced by J. M. Wordie for the "Southern Antilles") based on the soundings taken during the *Discovery* investigations of 1926–32, H. F. P. Herdman (*Discovery Reports*, vol. V, 1932, pp. 205–36) shows that concentric ridges join up the islands situated on the Scotia Arc, and that the evidence of the soundings strongly supports E. Suess's original view of the tectonics of this region.

Dr. W. A. Macfayden has investigated the fossil Foraminifera which have been found loose on the sea floor and also in shales dredged from the Burdwood Bank in the south-western Atlantic east of Staten Island (*Discovery Reports*, vol. VII, 1933, pp. 1–16).

These are found to be of Senonian and Lower Tertiary ages. This find thus confirms the view that the Burdwood Bank forms part of the Scotia Arc of folding, and makes a geological and tectonic link between Staten Island and South Georgia.

Dr. E. H. Kranck's exhaustive memoir on "Geological Investigations in the Cordillera of Tierra del Fuego" (*Acta Geogr. Helsingfors*, 4, No. 2, 1932, 231 pp.) represents the geological results of a Finnish expedition in 1928–29 for the investigation of peat. Tierra del Fuego is mainly built of a fold-mountain range consisting of highly metamorphic central schists of Devonian and Permo-Carboniferous ages, followed by a Permo-Triassic series of greywackes, argillites, radiolarites, ophiolites, and quartz-porphyries, then by Jurassic plant-bearing sandstones and shales with interbedded propylitic lavas, and finally by a Cretaceous "Flysch" series. Folding culminated twice, once in the Jurassic (Fuegian stage), involving the pre-Jurassic geosynclinal sediments and accompanied by intrusions of Cordilleran granite and diorite; and again in the Cretaceous, which folding involved the "Flysch" sediments only. Radiolarites and tuffaceous rocks occur on several horizons between the Permian and the Cretaceous, and some sort of correlation with the similar series of South Georgia may ultimately be established.

An enormous tome of 519 small quarto pages, with 48 plates and a number of maps, by R. Ijzerman ("Outline of the Geology and Petrology of Surinam, Dutch Guiana"), *Inaug. Diss. Univ. Utrecht*, 1931) must be one of the largest doctoral theses on record. Surinam is almost entirely composed of a crystalline basement complex of Pre-Palæozoic age which is traversed by basic igneous rocks of later date. The Roraima formation of sandstone and conglomerate, which bulks largely in British Guiana, is only known in one tabular mountain in the centre of Surinam. Full petrographical descriptions with numerous chemical analyses are given of the rocks. A good short summary of the geology of Surinam is given at the beginning of the work, and at the end there is a discussion of the geology in relation to that of neighbouring countries.

BOTANY. By Professor E. J. Salisbury, D.Sc., F.R.S., University College, London.

Ecological.—An analysis of three pasture areas, in the State of Quebec, associated with three soil types and differing also as regards climatic conditions has recently been published by Macdonald College (*Technical Bulletin*, No. 11, by D. E. Newton and F. S. Nowosad, March 1933) as a preliminary to further intensive studies on pasture problems. Of the areas selected that at Danville occupies

brown earth of slight acidity with an annual average precipitation of 49·4 in. The second area at North Hatley is situated on a highly acid podsol with an average precipitation of 40 in., whilst the third area at Philipsburg occupies an almost neutral brown earth overlying limestone with an average precipitation of about 38 in. The temperature in the three areas is very similar. The total number of "vascular" species in the three areas, in the order named, was 124, 150 and 167. The richest flora is thus associated with the most fertile soil of neutral reaction despite the lower rainfall, but the number of species of grasses and the percentage area they cover shows a positive correlation with the precipitation in the three areas. On the other hand the number of sedge species and the percentage area they cover shows a negative correlation with the same factor. The frequency of the dominant grasses would appear to be related to precipitation rather than to soil conditions. The most abundant species, *Agrostis alba* and *Poa pratensis*, respectively exhibit an increase and a decrease corresponding with decreasing precipitation. The estimated percentage area occupied by pasture weeds and the useful pasture grasses in aggregate does however show some indication of edaphic control since the pastures on the acid North Hatley soils exhibit a difference in this respect from those of the other two areas.

From Lysimeter studies of forest soils, Joffe concludes that loss of nitrates by leaching is inconsiderable and it is suggested that the rate of descent is sufficiently slow to permit of a considerable proportion of the nitrates being again taken up by the plants (*Soil Sci.*, vol. XXXV, p. 401, 1933). In the same journal (p. 413) Smith and Brown report observations on the diffusion of CO_2 through the soil. They conclude that in air-dry soil this is a linear function of the soil porosity, and not an exponential one as suggested by Buckingham.

Analysis of over 400 soil samples from Kentucky for Iodine showed a range in parts per million of from 0·8 to 16·9 with an average of 4·59 ppm. These figures compare unfavourably with the values obtained by Shore and Andrew for New Zealand (1–24 ppm.. av. 8·22) (McMargue and Young, *Soil Sci.*, vol. XXXV, p. 425). Samples examined from England and Scotland showed from 2·4 to 8 ppm., whilst high values have been reported from some islands. This marked variation of iodine content may well have important effects upon the fauna and indirectly or directly upon the flora.

The vegetation of Manchuria is at present little known so that the account by G. Fenzel (*Lignan Journ. Sci*, **12**, 11, 1933) is of interest. On Chanpai Mountain, the highest in Manchuria, which attains

2,800 m., the tree limit occurs at 2,000 m., where the forests are dominated by *Betula Ermanni* on the more exposed slopes and by *Larix dahurica* on the more sheltered. Below 1,750 m., the Larch is associated with *Abies nephrolopis*, whilst between 1,500 m. and 1,000 m. *Abies holophylla* is dominant, and *Pinus Koraiensis* between 1,000 m. and 750 m. Broad-leaved trees become important below 1,000 m. where *Juglans* and *Phellodendron* (to 800 m.), *Tilia manchurica*, *Quercus mongolica*, *Acer* and *Fraxinus* are characteristic constituents. The greater part of the Manchurian forests have been devastated by man during the last few decades and it is estimated that if their destruction remains unchecked they will disappear finally in ten or fifteen years.

Evidence is furnished by E Akerlund that there is an appreciable difference in capacity to withstand winter conditions between *Melandrium album* and *M. rubrum*. Of the former the percentage survivors varied from 55 per cent. to 68 per cent. according to situation, whilst only from 6 per cent. to 9·5 per cent. of the plants of *M. rubrum* survived. The percentage survival of the hybrid offspring between these species was appreciably higher than for *M. rubrum*, suggesting that hybridisation may sometimes be the means of facilitating the survival of a tender species under adverse climatic conditions (*Hereditas*, B. XVIII, p. 16, 1933). In the same journal (p. 122), O. Hagerup reports a study of the erect and prostrate types of *Vaccinium uliginosum*. The latter known as *f. microphylla* is in reality a distinct variety with only twelve chromosomes whereas the erect and larger-leaved "*f. genuina*" has a haploid number of twenty-four. The latter is therefore a polyploid and has a more southerly range than its prostrate congener which is abundant in east Greenland at 70° N. lat.

The loss of weight in litter under natural conditions, which has been studied by Falconer, Wright and Beal in pine-woods, is apparently affected to a marked degree by precipitation. An increase in rainfall from 5·7 in. to 14·8 in. was accompanied by an increase in the rate of decomposition of bracken stems from 5 per cent. to 9·1 per cent. The upper layers of the pinewood litter showed a rate of loss from 6·5 per cent. to 15 per cent. (*Amer. Journ. Bot.*, p. 196, 1933).

Morphology and Anatomy.—The phenomenon of twig abscission in trees is a familiar process in the Oak and Poplar. In the former weak laterals are usually involved and adverse conditions such as drought and age are known to accentuate the shedding of twigs whilst favourable conditions for growth reduce the abscission. In a recent study of the phenomenon in the Black Poplar (*P.*

Serotina), M. Thomas finds that the shed laterals are usually, though not invariably, reproductive, weak vegetative shoots being also involved. Practically no cambial activity is initiated by the reproductive buds and the same is also true for the weak vegetative buds. It is suggested that the consequential senescence of the conducting tissue may be the cause of the abscission (*Naturalist*, No. 915, April 1933).

From an examination of the trees and shrubs of Butler County, Pennsylvania, L. K. Henry finds sixty species with mycorrhiza of which twenty-six are additional records of mycorrhizal plants. Quite frequently it was found that both endotrophic and ectotrophic types of mycorrhiza occurred on different roots of the same plant and such "ectendotrophic" mycorrhiza were observed in seven species, viz. *Cornus paniculata, Fagus grandiflora, Quercus rubra, Viburnum acerifolium, Pyrus coronaria*, and *Robinia pseudoacacia* (*Bot. Gaz.*, vol. XCIV, p. 791, 1933.)

CYTOLOGY AND GENETICS.—An interesting hybrid between *Festuca rubra* and *Lolium perenne*, is recorded as occurring spontaneously by Nilsson (*Hereditas*, B. XVIII, p. 1, 1933). The somatic chromosome number was twenty-eight as compared with fourteen for *L. perenne* and forty-two (Stahlin) or fifty-six (Lewitsky and Kuzmina) for *F. rubra*.

Two of the microspecies of *Erophila verna* have been studied by O. Winge (*Hereditas*, B. XVIII, p. 181), viz. *violaceo-petiolata* with a haploid number of thirty-two chromosomes and a second characterised by fifteen chromosomes. Reproduction is not apogamous as has been suggested. Crosses between these microspecies are more or less sterile so that biologically they behave like Linneons.

S. K. Pande in *Current Science* for March 1933 records the development of the archesporium in *Notothylas levieri*, a common Himalayan member of the Anthocerotales. Unlike other members of this group, the archesporium here is entirely derived from the endothecium, thus resembling other Hepatics. The amphithecium, which in other Anthocerotales furnishes the archesporium, in this species gives rise to the wall only.

From a study of the embryo-sac development of *Saxifraga virginiensis*, M. Chapman has encountered certain unusual features, notably the occurrence of second divisions in the megaspore-mother-cell in planes at right angles to one another, producing T-shaped tetrads, also the presence of two embryo-sacs in the same ovule (*Amer. Jour. Bot.*, p. 151, 1933).

PLANT PHYSIOLOGY. By Professor Walter Stiles, Sc.D., F.R.S., The University, Birmingham.

Irritability.—A number of recent works on this subject deal with the geotropic response of seedlings. In a paper entitled "A Quantitative Study of the Geotropism of Seedlings with Special Reference to the Nature and Development of their Statolith Apparatus," Miss L. E. Hawker (*Ann. Bot.*, **46**, 121–57, 1932) presents data in respect to fifteen species chosen from dicotyledons, monocotyledons and conifers. She shows that as organs of limited growth such as the hypocotyl develop, the sensitivity to the gravitational stimulus first increases until it reaches a maximum and then falls off, for both the presentation time and latent time decrease to a minimum and then increase, the organ losing its sensitivity with cessation in growth in length. With organs of theoretically unlimited growth above ground, such as epicotyls, the sensitivity also increases to a maximum value and then falls slightly to a value which remains constant. With roots, both the presentation time and latent time fall to a minimum value at which they remain. Generally speaking, seedlings of dicotyledons are more sensitive to gravity than those of monocotyledons and conifers. Miss Hawker examined the statolith apparatus in about eighty species. In dicotyledons the statoliths in the hypocotyl or epicotyl are generally limited to the endodermis, although in a few arboreal dicotyledons as well as in some monocotyledons and conifers a statolith-containing tissue is found. In the radicle statoliths first appear in the root-cap. In all three groups of seedlings the sensitivity to gravity during development corresponds closely to the extent of statolith development. The results thus support the statolith theory of geotropism.

The statolith theory at first sight appears to be directly opposed to the hormone theory of geotropism according to which the curvature resulting from stimulation is brought about by a redistribution of a growth-promoting substance, or hormone. An investigation of the connection between geotropism and the distribution of the growth hormone has been made by H. S. Dolk ("Ueber die Wirkung der Schwerkraft auf Koleoptilen von Avena sativa, I," *Proc. K. Acad. Sci.*, Amsterdam, **32**, 40–47, 1929; also "Geotropie en Groeistof," Dissertation, Utrecht, 1930). Among other things he finds that although gravity does not affect the total amount of growth hormone formed in the oat coleoptile, yet on placing coleoptiles in a horizontal position the lower half of the coleoptile contains more growth hormone than the upper half, and as this will lead to more rapid growth of the lower half, the coleoptile will

in consequence develop an apogeotropic curvature. Miss Hawker has also investigated this question in roots of *Vicia faba*. She found that greater geotropic curvature can be induced in unstimulated roots of the broad bean by a hormone preparation from the lower halves of geotropically stimulated root tips than by the hormone preparation from the upper halves of the same root tips. She therefore concludes that the growth hormone accumulates to a greater extent in the lower half of a stimulated root than in the upper half, and that the hormone retards the growth of the root. The presentation time appears to correspond to the time taken for the redistribution of the hormone to take place. Similar results were obtained with roots of maize.

It is not yet clear whether the statolith theory and the hormone theory are to be regarded as mutually exclusive, or whether they represent alternative modes of action, or whether statoliths and hormones have any causal connection. It is, however, clear that statoliths as generally understood are not always necessary for geotropic preception as they are absent from many plant organs which exhibit definite geotropic response. However, fresh evidence that they are connected with geotropic behaviour appears in the work of Dorothea Mildebrath ("Untersuchungen über die Beeinflussung der geotropischen Reaktion nach Vorbehandlung mit Fluoresceinfarbstoffen und Salzen," *Bot. Arch.*, **34**, 161–215, 1932). Seeds were allowed to swell for twenty-four hours in solutions of various dyes (fluorescein, eosin and erythrosin) in a concentration of 0·0001 per cent., and of various salts (potassium chloride, sodium chloride, calcium chloride) in a concentration of 0·1 per cent. After such treatment the resulting seedlings generally exhibited a considerable lowering of their sensitivity to gravity and many of the roots were ageotropic. Along with the reduction in the sensitivity the viscosity of the protoplasm was greater while the content of statolith starch was less, changes both of which, on the statolith theory, would reduce the sensitivity to geotropic stimulation.

The changes in geotropic sensitivity during development in three species of lupin (*Lupinus albus, L. polyphyllus* and *L. arboreus*) have been investigated by Miss E. D. Brain ("A Comparative Study of Geotropism in Three Species of Lupinus," *Journ. Linn. Soc. Bot.*, **49**, 375–89, 1933). There is a definite ontogeny of graviperception and response in these seedlings as in those investigated by Miss Hawker to which reference has been made earlier. Both presentation time and latent time decrease with development of the hypocotyl and radicle, but no decline in sensitivity as observed by Miss Hawker was found in the hypocotyls of the lupin ; the maximum sensitivity

appears to continue until growth ceases. The radicles appear to behave similarly to those of the species examined by Miss Hawker. There is also a definite ontogeny of graviperception in the inflorescence. As the inflorescence develops the presentation time, at any rate in *Lupinus albus* and *L. arboreus*, decreases, thus showing an increase in sensitivity to geotropic stimulation. The three species show certain differences between themselves. Thus *Lupinus albus* is not affected in its response by the season of the year ; it responds equally in winter and summer. *L. polyphyllus*, on the other hand, shows a distinct decline in its response to gravity during the winter months. *L. arboreus* also gives less response in November than in March. These two latter species also exhibit a physiological zygomorphy, being more sensitive when stimulated in the cotyledonary plane than in a plane at right angles to this.

A great deal of work has been published during the last few years on the subject of phototropism, much of it dealing with the connection between phototropic response and the light-growth reaction. First may be noted two papers by N. Cholodny. In the first of these ("Mikropotometrische Untersuchungen uber das Wachstum und die Tropismen der Koleoptile von Avena sativa," *Jahrb f wiss. Bot.*, **73,** 720–58, 1930) a novel method is developed for determining the rate of growth of the coleoptile. Since growth during the stretching stage is brought about solely at the expense of water taken in, the rate of water absorption can be used as a measure of growth rate provided no water is given off. A micro-potometer was therefore devised, the coleoptiles being kept in a saturated atmosphere to prevent water loss. An increase in length of 1 mm. in the coleoptile corresponded to a movement of about 20 mm. of the water meniscus in the micropotometer. By the use of this apparatus it was shown that geotropic stimulation sufficient to induce a curvature does not involve any alteration in the rate of growth, an observation in line with those already noted in respect to the constancy in the quantity of growth hormone when the coleoptile or other organ is geotropically stimulated. A similar result was obtained with regard to phototropic stimulation. No marked alteration in growth rate was observed in coleoptiles stimulated sufficiently to produce a phototropic curvature. From these observations Cholodny drew the conclusions that the tropic reactions to gravity and light are not connected with any changes in the formation of the growth hormone, and that the conditions of illumination sufficient to produce a significant prototropic curvature do not induce a light-growth reaction. His experiments do not, of course, militate against the view of a redistribution of the hormone inducing the curvature.

In the second paper the relation of the light-growth reaction to phototropism is again discussed ("Lichtwachstumreaktion und Phototropismus," *Ber. deut. bot. Ges.*, **49**, 243–7, 1931). Here experiments are described in which isolated oat coleoptiles were suddenly illuminated from two sides. The coleoptiles then exhibit a typical light-growth reaction, the marked decrease in growth rate occurring after twenty to thirty minutes and lasting for somewhat longer before the normal rate of growth is resumed. But if instead of illuminating the coleoptiles suddenly they are subjected to slowly increasing illumination, a quite different result is obtained. The growth rate now increases along with the increase in light intensity and then, with the continuance of maximum illumination, slowly falls to its original value. The conclusion is therefore drawn that the so-called light-growth reaction is a sort of shock reaction resulting from exposing a plant or organ, that has been growing in the dark, suddenly to illumination.

A number of papers dealing with the phototropic response of *Phycomyces* have recently been published by E. S. Castle. The first of these ("Phototropism and Light-sensitive System of Phycomyces," *Journ. Gen. Physiol.*, **13**, 421–35, 1930) described experiments in which sporangiophores of this fungus were illuminated from above with an intensity of 86 foot candles and from the side with an intensity of 171 foot candles for periods varying from 0·005 to 0·6 second. It was found that the growth reaction and the phototropic curvature always synchronised. Provided the period of illumination exceeded a certain minimum the reaction time is the same for the two reactions. If the period of illumination is lower than this minimum the reaction time of both reactions increases, bearing an inverse relation to the period of illumination. It is therefore concluded that both the growth reaction and the phototropic curvature must be induced by the same light-sensitive system. From the numerical data obtained with regard to the relation between period of illumination and reaction time it is concluded that the rate of the processes during the latent time is directly proportional to the chemical change produced photochemically by the illumination.

In the next paper by Castle ("The Phototropic Sensitivity of Phycomyces as related to Wave-length," *Journ. Gen. Physiol.*, **14**, 701–11, 1931) measurements of the relative sensitivity of the sporangiophores to light from different regions of the spectrum were recorded. The greatest sensitivity was observed in the violet, and next in the ultra violet. Otherwise, the sensitivity became less as the wave-length of the light increased, the lowest value being

found at the red end of the spectrum, the activity of this light being only 0·12 per cent. of that of the violet light.

In his next paper ("Phototropic 'Indifference' and the Light-sensitive System of Phycomyces," *Bot Gaz.*, **91**, 206–11, 1931) Castle describes experiments on the "indifference" to phototropic stimulation exhibited by the sporangiophores of *Phycomyces* under certain conditions. He found that with highly sensitive sporangiophores phototropic indifference, that is, a failure to react to stimulation, occurred over a wide range of exposures varying from continuous illumination to 0·6 second, when the intensity of illumination was 171 foot candles. With a shorter period of illumination, however, the sporangiophores reacted to unilateral illumination with a positive curvature. It was also found that exposure of such a sporangiophore to lateral illumination for any length of time produced a distinct growth reaction. The indifference to tropic stimulation is therefore not characterised by an absence of a light effect, but by failure of the light to produce differential rates of growth on the two sides of the organ. Light exposures of less than 0·6 second involved a longer reaction time the shorter the exposure. The conclusion was therefore drawn that with these short exposures not enough chemical change takes place to enable the processes to go on at the maximal rate. It thus appears that with an intensity of 171 foot candles and exposures of 0·6 second or longer, the processes involved during the latent period proceed at the maximal rate; with shorter exposures the rate is sub-maximal and the less illumination of the side of the organ remote from the source of light involves a slower rate of these processes in that side than in the side nearer the source of illumination, with, consequently, a differential rate of growth on the two sides resulting in a curvature.

In the fourth paper ("On 'Reversal' of Phototropism in Phycomyces," *Journ. Gen. Physiol.*, **15**, 487–9, 1932) Castle deals with the reversal of phototropic curvature which results when the light intensities are so high that the "indifference" dealt with in the last paper gives place to a negative curvature. He shows that this reversal of the curvature is due to infra-red radiation from the source of light and can therefore be regarded as negative thermotropism. By the use of a copper sulphate filter to absorb the infra-red radiation he was able to show that devoid of these rays high light intensities produce indifference, which can be accounted for as shown in the previous paper discussed above.

The work of O. Wiechulla ("Beiträge zur Kenntnis der Lichtwachstumreaktion bei Phycomyces," *Beitr. z. Biol. Pflanze*, **19**, 371–419, 1932) supports in general some of that of Castle. It is

shown that the phototropic reaction and the growth reaction in *Phycomyces* with equal illumination are equal. The results obtained with different coloured lights, as pointed out by J. Buder ("Über die phototropische Empfindlichkeit von Phycomyces für verschiedene Spektralbezirke," *Beitr. z. Biol. Pflanze,* **19**, 420–35, 1932), agree well with those obtained by Castle, although they differ from those obtained years ago by Blaauw. The difference, according to Buder, is probably to be attributed to the different methods employed, and experiments are in progress having for their object the explanation of the different results given by the respective methods.

Lastly reference may be made to a paper by H. Buch ("Über den Phototropismus der Panizeen," *Mem. soc. pro Fauna et Flora Fennicæ,* **6**, 167–73, 1931). It is generally supposed that in the Paniceæ the phototropic curvature of the hypocotyl results from perception of the stimulus by the coleoptile. Buch shows, by completely shading the latter, that sufficiently strong illumination of the hypocotyl will itself induce phototropic curvature in that organ.

ZOOLOGY. By F. W. Rogers Brambell, B.A., Ph.D., D.Sc., University College of North Wales, Bangor.

The development of the spermatozoon of the crab, *Paratelphusa spinigera,* is described by Nath (*Q.J.M.S.*, **75**, 1932). As is well known the sperms of Decapod Crustacea have an unusual and fantastic form and are not flagellate like the majority of those of other animals. In this paper it is shown that the sperm of the crab possesses all the usual components of a typical sperm. The nucleus is in the form of a deep cup with the ring-like acrosome fused with its margin. At the bottom of the cup lies the vesicular proximal centrosome and above it, filling the greater part of the cavity of the cup, is the mitochondrial vesicle. The mouth of the cup is plugged by the ring-like distal centrosome. The thick axial filament arises from the bottom of the cup and, piercing both the proximal centrosome and the mitochondrial vesicle, ends just below the distal centrosome. The acrosome is formed during spermateleosis by the Golgi elements. It is suggested that at the time of fertilisation the sperm changes from its characteristic form into that of a typical flagellate spermatozoon.

The ciliary feeding mechanism of the Entoproct Polyzoa is dealt with in a paper by Daphne Atkins (*Q.J.M.S.*, **75**, 1932). The structure of the lophophore and the tentacles is described. It is shown that the long lateral cilia on the tentacles cause a current of water to pass inwards between them and throw food particles on to

the short frontal cilia of the inner surface, which carry them down to the groove leading to the mouth. It is suggested that the lateral cilia of the tentacles of *Loxosoma crassicauda* are under the nervous control of the animal. A note on the ciliary feeding mechanism of *Flustrella hispida* is given. The methods of feeding in the Entoprocta and Ectoprocta are compared, and it is shown that they are widely different.

The habits, structure and development of *Spadella cephaloptera* are described by John (*Q.J.M.S.*, **75**, 1933). This is the smallest species of Chætognath known, the adults not measuring more than 5 mm. in length. It occurs in tidal pools in Plymouth Sound and also in some of the tanks of the Marine Biological Laboratory, Plymouth. It is shown in the present paper for the first time that it is essentially a shallow water form, loving tidal pools, and is not pelagic like other Chætognatha. A full and very interesting account is given of its habits, even the transference of sperms from one individual to another having been observed. The detailed description of the anatomy of this species is particularly valuable in view of our scanty knowledge of the Chætognatha as a whole and of *Spadella* in particular. The development is also worked out in some detail from material reared in the laboratory. Breeding proceeds throughout the year and the eggs, which are laid in clusters, are attached to some suitable object below water level. This is unlike the eggs of *Sagitta*, which are pelagic and float freely on the surface of the water. Segmentation is regular and complete and results in the formation of a spherical blastula. Gastrulation takes place by invagination. A single cell, the primordial germ cell, differentiates from the other cells of the lining of the anterior end of the archenteron in the early gastrula. It soon becomes free in the archenteric cavity and then divides into two. The blastopore closes completely. The archenteron is divided by the backward growth of folds into its cavity resulting in the formation of a cœlomic pouch on each side of the median part of the archenteron which will give rise to the gut. These folds then join posteriorly, cutting off the gut in front from the median part of the archenteron behind, but leaving the lateral cœlomic pouches opening into the latter. The germ-cells pass into the posterior part of the archenteric cavity and move to opposite sides, so that at a later stage when the back growth of the gut has completely separated the two cœlomic pouches, one germ cell is present in each. By this time the nucleus of each germ-cell has divided into two. These cells give rise to the gonads ultimately, but the differentiation into ovary and testis is only brought about by the division of the gonad, caused by the development of the

septum separating trunk and tail cavities, into an anterior ovarian portion and a posterior testis. The stomodæum is formed by an ectodermal invagination. The ganglion cells differentiate and sink in from the ectoderm. The embryo lengthens and finally hatches forty-eight hours after laying.

The tendency of the larvæ of many Echinoderms to form a primary madreporic pore on the right side as well as the normal one on the left side is fairly well known and many such larvæ have been described. It is more marked in some species than in others. This tendency to produce double-hydrocœled larvæ in *Asterias glacialis* has been investigated experimentally by Narasimhamurti (*Jour. Exp. Biol.*, **10**, 1933). Following the observation of MacBride that hypertonic solutions of sea-water encouraged the production of double-hydrocœled larvæ in *Echinus miliaris*, the effect of such solutions on the larvæ of *Asterias glacialis* was examined. Five hundred larvæ of this species were reared to the eighth day in hypertonic sea-water, of which 159 developed a double hydropore. Five hundred reared in normal sea-water only produced 59 individuals with a double hydropore. It would appear, therefore, that the treatment with hypertonic sea-water tended to produce double hydrocœled larvæ.

The rheotactic responses of Planaria have been investigated by a number of workers, the most recent paper on the subject being by Beauchamp (*Jour. Exp. Biol.*, **10**, 1933). Sexual development in the species investigated, *Pl. alpina*, is dependent on low temperatures and sexual individuals are rarely found at temperatures above 10° C. Thus sexual individuals can be found at any time of the year in cold springs where the temperature is always below 10° C., but in the lower part of the stream, which warms up in summer, they are only found when the temperature is sufficiently low, usually in winter. It is shown that sexual development is accompanied by positive rheotaxy. Thus when the planarian population of a stream develops sexually it tends to move up against the current and a general migration up stream occurs. This migration results in overcrowding of the planarians at the source of the stream with shortage of food and consequent starvation. Starvation results in de-differentiation of the reproductive organs and consequent loss of positive rheotaxy, which is the fate of most of the animals, but some succeed in completing the sexual cycle and then they also become negatively rheotactic. All the animals, now exhibiting negative rheotaxy, migrate again down stream. Finding an adequate food supply and providing temperature conditions are still suitable they redevelop sexually and again move up stream. Thus the state of

development and consequently the rheotactic behaviour (including the migrations up and down stream) of *Pl. alpina* are governed by the temperature and the food supply.

ENTOMOLOGY. By H. F. Barnes, M.A., Ph D., Rothamsted Experimental Station, Harpenden.

General Entomology —The general conclusions regarding the fauna of the Seychelles and adjacent islands have now been written up by H. Scott (*Trans Linn. Soc. London*, **19**, 1933, 307–91). The Percy Sladen Trust sent two expeditions to these islands, the H.M.S. *Sealark* expedition of 1905 and another in 1908–09. It is obviously impossible to summarise here the results obtained from such an intensive study. It is suggested that a recent review article on biological peculiarities of oceanic islands by A. Gulick (*Qtly. Rev. Biol.*, **7**, 1932, 405–27) should be read in conjunction with Scott's paper. There is also an article on entomological research in the Marquesas islands by H. Scott (*Nature*, **130**, 1932, 797–8).

E. M. Walker has considered prognathism (the forward position of the mouth and jaws) and hypognathism (the downward position) in insects (*Canad. Ent.*, **64**, 1932, 223–9). One of his conclusions is that the position of the mouth and mouth-parts in mandibulate insects varies greatly according to habits, such as those of feeding, locomotion and surface contact. Both types are met with in the Apterygota and the Pterygota. The prognathous type of head in orthopteroid insects is believed to be the primitive type, yet hypognathism appeared in some of the earliest groups of fossil insects, e.g. Megasecoptera, and its occurrence in the Odonata and Ephemeroptera is probably of extremely ancient origin. The evolution of the insect head and the organs of feeding is the subject of an important paper by R. E. Snodgrass (*Smith. Rept. for 1931*, 443–89, Pub. 3160).

A remarkably interesting contribution on the relation of weight to wing area in the flight of animals has been made (*Jl. Malayan Branch Roy. Asiatic Soc.*, **8**, 1930, 334–60). E. Banks has shown that lighter fliers have a larger wing area relative to weight than heavy ones and has expressed the relation of wing area to weight graphically by a number of approximately parallel curves representing various orders and sub-orders in birds, flying fishes and insects. He has also calculated and obtained the " constant," $3\frac{\sqrt{\text{wing area}}}{\sqrt{\text{weight}}}$, which varies from 5·8 to 2·8 in birds and bats and from 12·6 to 1·6 in insects, but mostly from 6 to 3 ; so that the " constant," which

is primarily a geometrical property and not a consequence of any essential biological factor, is possibly the same for all, about 4.

The nocturnal activities of insects has for a long time attracted attention; recently, however, this type of study has developed along ecological lines. For example, O. Park, J. A. Lockett and D. Myers (*Ecology*, **12**, 1931, 709–27) showed that the activity of the nocturnal fauna of a forest was in apparent correlation with the rhythmic expression of such factors as light intensity, temperature, relative humidity and rate of evaporation within the association. In a second study (*loc. cit.*, **13**, 1932, 335–46), O. Park and J. G. Keller have brought to light one of the dangers of generalising. In an investigation into the night activity of some carnivorous beetles and a cockroach, it was found that they were active at night and inactive during the day under relatively normal fluctuations of the factor complex. In complete darkness, with temperature and evaporation rate constant, the cockroach tended to give maximal activity until apparently fatigued. On the other hand an herbivorous Tenebrionid under the same conditions continued to exhibit its normal night activity and day inactivity. Such behaviour is considered a strict periodicity of activity. Even adults reared from the larval stage in complete darkness gave the same form of nocturnal rhythm. These two types of nocturnal activity must be considered quite distinct and separately.

The effects of X-rays on insects has been studied chiefly from a genetical point of view. However, Koidsumi (*Jl. Soc. Trop. Agric.*, **2**, 1930, 243–62) summarised the literature concerned with the effect of X-radiations on insects from other points of view. G. L. Hey (*Jl. Expt. Zool.*, **64**, 1932, 209–30) has made a preliminary study of the effects of X-rays on the various stages of the bean weevil. He obtained a certain number of pronounced abnormalities, such as abnormal antennæ, legs, wings and the inability to walk without any other visible alteration. It has been suggested with some support that natural radiations induce mutations in nature and that artificial treatment of this kind increases the proportion of such abnormal forms. In a similar way, M. E. MacGregor was studying the pathological effects of ultra-violet radiation on mosquito larvæ and pupæ (*Proc. Roy. Soc.*, **B**, **112**, 1932, 27–38). Irradiation in this case resulted in a peculiar form of fatal injury. The histolysis of the tissues caused was of a progressive type affecting even adjacent cells from which the injury continued to spread.

The influence of temperature on the life history of insects, with special reference to experiments with the cotton worm *Prodenia littoralis*, is the subject of a paper by E. Janisch (*Proc. Ent. Soc.*

London, **80**, 1932, 137–68). General principles, such as length of development and temperature, the course of development, mortality, and range of variation are discussed rather mathematically, followed by some general conclusions and summary. K. Mellanby (*Parasitology*, **24**, 1932, 419–28) has studied the effect of temperature and humidity on the metabolism of the fasting bed-bug (*Cimex lectularius*) and P. A. Buxton (*loc. cit.*, 429–39) similarly has dealt with the relation of the adult *Rhodnius prolixus* to atmospheric humidity. In the former paper a comparison is made between the results W. Zwölfer (*Zeits. f. angew. Ent.*, **19**, 1932, 497–513) has described methods for regulating temperature and air humidity which should be useful in connection with insect ecological studies. G. A. Mail, in a paper on winter temperature gradients as a factor in insect survival, shows the small fluctuation of soil surface temperatures under a snow covering compared with air temperatures (*Jl. Econ. Ent.*, **25**, 1932, 1049–53). In other words, there is no correlation between the winter air temperatures and soil surface temperatures.

In a review article F. S. Bodenheimer (*Qtly. Rev. Biol* , **8**, 1933, 92–5) deals with discontinuous and abrupt growth in insects and shows that Przibram's growth factor is valid. Przibram found, in *Sphodromantis viridis*, a quotient of 2 for the weight of every stage as divided by the preceding one. For length this quotient proved to be 1·26 ($= \sqrt[3]{2}$). Then he stated these quotients to be a general rule in the growth of Arthropoda. Bodenheimer has extended these studies to all insect orders and shown that insect growth follows a progression factor of 2 or $n \cdot 2$ for weight, and of $\sqrt[3]{2} = 1{\cdot}26$ or $n \cdot 1{\cdot}26$ for length. The increase of latent divisions in the Holometabola obscures these relations, without invalidating them.

H. Munro Fox and G. Pugh Smith (*Jl. Expt. Biol.*, **10**, 1933, 196–200) have followed up the idea that muscular hypertrophy may be due to a hormone produced during muscular activity and that such a hormone may influence other parts of the body of an animal. They fed blowfly (*Calliphora erythrocephala*) larvæ on resting and fatigued muscle of the frog. The larvæ fed on fatigued muscle attained a bodyweight of 9 per cent. greater than those fed on resting muscle and the rate of their heart beat was increased by 14 per cent. The length of larval life and the oxygen consumption was the same in the two sets of larvæ. It would be interesting to see whether or not the pupal duration were altered.

The need for correlation of biochemical changes taking place in the life cycles of insects with environmental conditions such as food plants, composition of soils, etc., is apparent to all entomologists.

Unfortunately very few are qualified to enter this field of research. Occasionally, however, contributions are made. W. Rudolfs, who incidentally is chief of the department of sewage research at the New Jersey Agric. Expt. Station, has been studying chemical changes during the life cycle of the tent caterpillar (*Malacosoma americana* Fab.). In a fifth paper (*Jl. N.Y. Ent. Soc.*, **40**, 1932, 481–8) he has presented weights and measurements of growing larvæ together with a brief general summary.

R. T. Cotton (*Jl. Econ. Ent.*, **25**, 1932, 1088–1103), in a study of the relation of respiratory metabolism of insects to their susceptibility to fumigants, has shown that the susceptibility of an insect to a fumigant is influenced by any factor that increases the rate of metabolism of that insect. An increase in rate of metabolism increases the insect's susceptibility and vice versa. Three of the most important factors which increase the susceptibility are dealt with: an increase in temperature; an increase in the carbon-dioxide content of the fumigation chamber; and a decrease in the oxygen content of the chamber. R. Kirschner (*Zeits. f. angew. Ent.*, **19**, 1932, 544–56) has investigated the effect of gas forming insecticides on the heart beat in *Macrosiphon tulipæ*.

F. M. Jones (*Proc. Ent. Soc. London*, **80**, 1932, 345–86) has conducted a series of experiments designed to show the relative acceptability of insects to birds and the basis of any discrimination that might be observed. They were carried out in Massachusetts. Known numbers of freshly killed insect species were placed on trays and the birds which visited them were observed from a distance. In addition a number of experiments were carried out in an attempt to demonstrate the possession of distasteful or possibly of poisonous qualities in some of the insects avoided by the birds and in a manner which eliminated the colour factor from the problem. Infusions of the insects mixed with food of known acceptability to ants were the basis of this section of the work. The ant used was *Solenopsis molesta* and the test foods were spread upon a white enamelled plate in small numbered areas. Thick fresh cream was found to be a suitable food medium for the tests. Among the conclusions reached were that the insect acceptability to birds is relative, that the causes of it are complex and that insect coloration has material influence upon insect acceptability. Further the experiments with ants demonstrated the presence of a deterrent in a few insects, also that the food of insects found to possess these ant-deterrents, consists of the leaves and juices of related acrid and poisonous plants and that the relative unacceptability of many insects to birds must depend upon other factors, not upon plant-derived deterrents.

While it is common knowledge that insects act as vectors of human diseases and plant diseases, it is only in isolated cases that insects are known to be carriers of insect diseases. Nellie M. Payne (*Ent. News*, **44**, 1933, 22) has shown that the sporozoan disease of the Mediterranean flour moth caused by *Thelohania ephestiæ* Mattes is transferred by the parasitic wasp *Microbracon hebetar* Say. This disease cannot be transferred by the mouth. The disease follows parasitic attack and the first point of infection is in the ganglion pierced by the parasitic wasp. Later the causative organism is found in both the nervous system and the fat body.

Three new methods are described by D. G. Hall, J. B. Hull and W. E. Dove (*Ent. News*, **44**, 1933, 29–32). The first of these is an insect trap for use on the headlight of a motor-car ; they also report a preserving fluid (95 per cent. ethyl alcohol 85 c.c., 10 per cent. formalin 15 c.c., glycerine 5 c.c.) which gives natural shape and colour in specimens of sand flies ; and thirdly Hetherington's solution for nematodes is stated to be useful in fixing and clearing dipterous larvæ and non-pigmented insects for microscope slides.

A general account of the insects of coconuts in Malaya has been written by G. H. Corbett (*Fed. Malay States Dept. Agric.*, Gen. Ser. No. 10, 1932, 106 pp.).

Orthoptera.—In a third paper on insect development Eleanor H. Slifer (*Biol. Zentralb.*, **52**, 1932, 223–9) describes blastokinesis in the living grasshopper egg. This phenomenon is the turning of the partially formed embryo in the egg. It is accomplished in this case by vigorous movements of the embryo itself. In exceptional cases when blastokinesis fails to occur development may continue resulting in an animal of normal appearance.

In an article on apterism and subapterism in the cockroaches of the subfamily Blattinæ (*Ent. News*, **43**, 1932, 201–6), J. A. G. Rehn comes to the view that the factors producing brachypterism in this group, as in other subfamilies of the Blattidæ, cannot be considered geographic *per se*, although environmental and other influences, such as altitude and possibly humidity and aridity under special conditions, appear to be, or have been, motivating causes.

Coleoptera.—D. E. Fink (*Jl. Agric. Res.*, **45**, 1932, 471–82) has shown that arsenic does not influence the digestive enzymes of Colorado beetles fed on sprayed foliage to the extent of inhibiting their normal activity. On the other hand, the injection of arsenical suspensions directly into the insect mouth results in complete inhibition of the activity of the proteolytic enzymes. Using the results of the author's previous experiments on the effect of arsenicals

on the respiratory metabolism of insects, it can be concluded that arsenicals exert a more profound effect on cellular respiration than on the activity of digestive enzymes of this beetle.

A new antennal organ, which is supposed to be secretory in function, has been described by S. Maulik in the chrysomelid beetle *Agetocera* (*Proc. Zool. Soc. London for 1932*, 1932, 943–56).

After studying the single character of colour pattern in the geographical variation of ladybird beetles (*Coccinellidæ*), T. Dobzhansky (*Amer. Nat.*, **67**, 1933, 97–126) has come to the conclusion that so far as this character is concerned there is no essential difference between the non-geographical and geographical variation.

Lepidoptera.—In a study of the life history of the Small Eggar moth, *Eriogaster lanestris* L. (*Proc. Zool. Soc. London for 1933*, 1933, 161–80), F. Balfour Browne shows how cocoons obtained under artificial conditions vary in colour from a dark brown to white and the colour depends largely upon the amount of moisture present. Pale cocoons placed in saturated air darkened within 24 hours, but dark cocoons placed in dry air did not go back to pale colours. The work of Poulton and Bateson in this connection is discussed. The author also discusses monophagy and polyphagy.

An important paper by O. W. Richards and W. S. Thomson (*Proc. Ent. Soc. London*, **80**, 1932, 169–250) on the genera *Ephestia* and *Plodia* is to a large extent systematic In addition there is a section on the parasites and predators of the early stages.

There is an interesting study on the urticating hairs of caterpillars by P. R. Tonkes (*Bull. Biolog. France et Belgique*, **67**, 1933, 44–99).

O. Querci (*Ent. Rec.*, **44**, 1932, 168–76) has given a very suggestive account of his studies at Philadelphia on the biology of *Pieris rapæ*. He states that heat above 90° F. killed larvæ but not eggs or pupæ, and found that when the mean temperature is above 60° F. a new brood occurs about every 18 or 19 days and that the duration of every brood is at least 15 days longer than that of its predecessor and so all the broods except the first overlap.

Hemiptera.—H. Hacker (*Queensland Agric. Journ*, **37**, 1932, 262–3) has described a new species of Peloridiidæ from Queensland. This insect was found to be a forest insect associated with the antarctic beeches of the genus *Nothofagus*. W. E. China (*Ann. Mag. Nat. Hist.*, **10**, 1932, 392–5) has summarised the distribution of other species in this interesting family. One occurs in the vicinity of the Straits of Magellan, another in New Zealand, another in Tasmania and this new species in Queensland. *Nothofagus* spp. are known to occur in all these localities. It seems reasonable to suppose that

the McPherson Range in Queensland is a relic island of the ancient antarctic fauna and flora comparable to the European Alps.

A rather amazing state of affairs in connection with insects carrying virus diseases has been revealed by the work of H. H. Storey (*Proc. Roy. Soc.*, **B**, **112**, 1932, 46–60). He has shown conclusively that there are two distinct races of the leafhopper *Cicadulina mbila* Naude. One of these is able to transmit the virus of streak disease in the natural process of feeding on maize plants. The other race is unable to do this. Furthermore he has shown that the ability to transmit is inherited as a simple dominant factor, linked with sex.

Following her study, previously noted, of the structure and development of the reproductive system in the Coleoptera, Margot E. Metcalfe (*Q.J.M.S.*, **75**, 1932, 467–82) has now written up some notes on the reproductive organs in *Philænus spumarius* L.

W. M. Davies has studied the intensity of population of aphids and developed a technique to ascertain their movement within a crop (*Bull. Ent. Res.*, **23**, 1932, 535–48).

Hymenoptera.—Physiological changes during hibernation and the period of rest or diapause in the wasp *Scelıphron cæmentarium* have been investigated by J. H. Bodine and T. C. Evans (*Biol. Bull.*, **63**, 1932, 235–45). The occurrence of the diapause is independent of environmental temperatures, but its duration is conditioned to an appreciable degree by these factors. Cyclic or rhythmic changes in oxygen consumption and body weight during the developmental life cycle of the wasp were also found.

A. M. Vance and H. D. Smith (*Ann. Ent. Soc. Amer.*, **26**, 1933, 86–94) have made a study of the larval head of parasitic Hymenoptera and the nomenclature of its parts. This paper should be useful as a basis for future descriptions as several recent workers, for example W. H. Thorpe, have shown the value of larval head characters in separating species and genera.

The great preservative property of the sting of the parasite *Aenoplex carpocapsæ* upon the larvæ of the codling moth is a matter for comment. H. E. McClure (*Ent. News*, **44**, 1933, 48–9) states that stung larvæ remain fresh for a maximum of 73 days with an average of 26 days and minimum of 41 hours. The period of deterioration, *i.e.* when the skin was discolouring in places, averaged 12½ days with a maximum of 26 days and a minimum of 42 hours.

A relation has been established between the size of host puparia and sex ratio of the Braconid parasite *Alysia manducator* by F. G. Holdaway and H. F. Smith (*Australian Jl. Expt. Biol.*, **10**, 1932, 247–59). Small puparia produce a high proportion of males

and large puparia a high proportion of females. The explanation of this correlation between host size and sex of *Alysia* has not yet been found.

Diptera.—The distribution of air in the œsophageal diverticula and intestine of mosquitoes in relation to emergence, feeding and hypopygial rotation has been studied by J. F. Marshall and J. Staley (*Parasitology*, **24**, 1932, 368–81). E. H. Hinman (*Ann. Ent. Soc. Amer.*, **26**, 1933, 45–52) has reported the result of his inquiry into the enzymes in the digestive tract of mosquito larvæ. The effect of salt on the anal gills of the mosquito larva, the function of the anal gills, and the adaptation of such larvæ to salt water are the titles of three papers by V. B. Wigglesworth (*Jl. Expt. Biol.*, **10**, 1933, 1–15, 16–26 and 27–37).

Margot E. Metcalfe has described the morphology and anatomy of the larva of *Dasyneura leguminicola* (*Proc. Zool. Soc. London for 1933*, 1933, 119–30). Very few such studies have been made in the family of gall midges.

The embryology of *Sciara* has been worked out in detail by Anne M. du Bois (*Jl. Morph.*, **54**, 1932, 161–96). It follows practically the classical scheme of the development of Diptera and in this study certain points which are peculiar to *Sciara* and in direct connection with the special genetic behaviour of these flies have been considered.

A. E. Michelbacher, W. M. Hoskins and W. B. Herms (*Jl. Expt. Zool.*, **64**, 1932, 109–32) in a study of the adequacy of sterile synthetic diets for the nutrition of flesh-fly larvæ, *Lucilia sericata*, have found that technical casein, with agar solution to prevent drying, allowed good growth. Highly purified casein was a very deficient food, but the addition of yeast, mineral salts and butter or cod-liver oil gave good results, except for irregularity in shape of the pupæ. Addition of a small amount of cystine resulted in perfect pupæ and as rapid growth and as high pupation and emergence as occurs on natural contaminated flesh. J. G. Haub and D. F. Miller have studied the food requirements of blow-fly cultures used in the treatment of osteomyelitis (*loc. cit.*, **64**, 1932, 51–6). They find that lean beef was the most satisfactory, the maggots becoming adults in ten days. Although differences in food produced corresponding differences in the length of time required to complete larval development, the duration of the pupal stage did not vary. The average length of oviposition was 30 days when the eggs were collected three times a week and the adults were fed on brick sugar, fresh lean beef and fresh water.

An account of the buccopharyngeal mechanism of a blow-fly

larva (*Calliphora quadrimaculata* Swed.) has been written by D. Miller (*Parasitology*, **24**, 1933, 491–9). The same author has given an historical review of New Zealand Muscidæ and Calliphoridæ (*Bull. Ent. Res.*, **23**, 1932, 469–76). This is the first of a series of papers on their biology and economic status.

After some preliminary experiments D. E. Beck (*Jl. N.Y. Ent. Soc.*, **40**, 1932, 497–501) has reached a tentative conclusion that the greater the percentage relative humidity, temperature remaining constant, the greater will be the emergence of *Rhagoletis suavis* Cress., the Walnut husk maggot (Trypetidæ).

An empirical equation describing the egg-laying curves of *Drosophila* has been formulated by H. Shapiro (*Biol. Bull.*, **63**, 1932, 456–71). The equation for the rate of laying is independent of variations among individuals in life span, active egg-laying period and total egg output.

More than twenty new forms of traps and variations of tsetse traps are described in a paper by C. F. M. Swynnerton (*Bull. Ent. Res.*, **24**, 1933, 69–106). T. A. M. Nash (*loc. cit.*, **24**, 1933, 107–57) has contributed a full account of the ecology of *Glossina morsitans*. Other recent papers by A. W. J. Pomeroy and K. R. S. Morris, and A. W. Taylor on the tsetse-fly problem are to be found in the same journal (**23**, 1932, 501–34 and **23**, 1932, 463–7). B. Jobling (*Parasitology*, **24**, 1933, 449–90) has redescribed the structure of the head, mouth-parts and salivary glands of *Glossina palpalis*.

Other Orders.—V. B. Wigglesworth (*Parasitology*, **24**, 1932, 365–7) has described the hatching organ of *Lipeurus columbæ* Linn. (Mallophaga). It is very similar to that previously described in sucking lice and unlike that of any other group of insects. This resemblance is further evidence for the affinity on the mallophaga and Siphunculata.

An attempt has been made by H. E. Ewing to homologise the various structures in the male genital armature in the order Anoplura or sucking lice (*Ann. Ent. Soc. Amer.*, **25**, 1932, 657–69).

A. Vandel (*Bull. Biolog. France et Belgique*, **67**, 1933, 125–33) has described in detail a case of sexual inversion produced by a Strepsipteron of the genus *Pseudoxenos* in *Odynerus innumerabilis* Saussure.

The termite, *Termopsis nevadensis*, has been shown by S. F. Cook (*Biol. Bull.*, **63**, 1932, 246–57) to possess wonderful powers for meeting adverse environmental conditions. It can extract practically the last traces of oxygen in a closed space and then continue to live for as long as two days in the absence of oxygen. It can also survive when the carbon dioxide is as high as 20 per cent. The same

author with K. G. Scott (*loc. cit.*, **63**, 1932, 505–12) has studied the relation between absorption and elimination of water in another species of termite, *T. angusticollis*. This species loses water rapidly when placed in dry air and fatal results may follow unless this loss is compensated. Water for replacement is provided as liquid in the food, and the animal is unable to take up water vapour actively even from a moisture-saturated atmosphere.

NOTES

Locust Control[1] **(H. F. B.)**

Until recently, in spite of the fact that locust outbreaks have occurred since time immemorial and although a large amount of research concerning them has been done, no real advance had been made in attempts to control them or to limit the damage caused. One reason perhaps for this comparative failure was the lack of any co-ordination and also the giving of research grants only during outbreaks. This, maybe, has allowed interesting biological research to attract the attention of investigators away from the real problem.

The present outbreak of the Desert Locust in British territories in Africa and Western Asia started in 1925, and had attained such alarming dimensions by 1929 that a sub-committee was appointed to consider and report on means for the mass destruction of this pest. At first this body was attached to the Committee of Civil Research but later became a committee of the Economic Advisory Council. The appointment of committees too often leads to stagnation, yet in this instance remarkable progress has been made. Existing information has been studied and arrangements have been made for the collecting and summarising of current data on the appearance and movements of this locust both from the British colonies and dependencies and also from non-British territories. Thus a steady source of information is now available. This work, made possible by financial support from the Empire Marketing Board and the Imperial Institute of Entomology, has been carried out at the latter Institute under the direction of Mr. B. P. Uvarov, the well-known authority on locusts, who has written this report. In addition, the Imperial Institute of Entomology was recognised in 1931 as the international centre for information about locusts and so uniformity of action on a much larger scale has been made possible. The Institute has

[1] *The Locust Outbreak in Africa and Western Asia*, 1925–31. Survey prepared by B. P. Uvarov for the Committee on Locust Control, Economic Advisory Council, 1933. Price 5*s*. net, postage extra. Obtainable from His Majesty's Stationery Office or through any Bookseller. 87 pp., with 13 maps in cover.

become the clearing-house for data from British, Belgian, French and Italian territories in Africa. In this year also the terms of reference of the committee were extended to include other tropical African locusts.

The report forms a general survey of the present outbreak of locusts from its beginning in 1925 up to the end of 1931. A full list of papers published in connection with this outbreak is given in the bibliography which covers nearly 25 pages. Besides these Mr. Uvarov has examined nearly 800 manuscript documents. He has attempted to reconstruct a connected picture of the development of the outbreak of each species of locust. Certain tentative hypotheses have been formulated and used in this connection.

The survey shows, for example, how in a period comprising only about five generations, the Migratory Locust crossed the continent of Africa from east to west and also during the next two generations well south of the equator. The enormous scale of the outbreak showed the futility of attempts to control it and so the policy of large-scale campaigns in east Africa was abandoned and it was decided to concentrate on measures aiming only at the immediate protection of threatened crops. The practical results of this were very satisfactory so far as saving standing crops, but the spread of the swarms as well as their size and number were almost unaffected. One reads that the only hope for its cessation lies in the change of general conditions (climatic in the first instance) in a direction unfavourable to the reproduction of the insect. Thus the lesson has been taught that it is impossible to control an outbreak once it has started.

It is pointed out, and emphasised again, in the preface by Sir Henry Miers, that the damage in the present outbreak can be safely estimated at more than £6 millions. The potential danger from locusts will, it is stated by Mr. Uvarov, increase directly in proportion to the increase in the value of the crops, while the chances of wandering swarms settling on crops instead of on the uncultivated lands will become greater when larger areas are under cultivation. As the agricultural development of Africa is really only in its infancy, the danger is obvious.

The impossibility, or at any rate the enormous cost, of controlling a locust invasion cannot be disputed. Mr. Uvarov comes to the conclusion that the solution of the problem lies in the discovery of means for the *prevention of outbreaks*. It is in this connection that the co-ordination of efforts has been directly successful. Some definite regularities in the distribution, breeding and migration of locusts have been discovered and also the fact that the species of

locusts are restricted to definite vegetation zones and that migration is regulated by seasonal climatic changes. The regions where swarms arise in the first instance are not yet sufficiently known. This discovery would mark a big step in the direction of practical locust control as the breeding areas could be kept under observation and the incipient swarms controlled as they arose. However, it can be expected that some breeding-grounds would be inaccessible and so it is decidedly useful to know the routes taken by the swarms. These movements which are fairly regular have already been par- ially discovered.

Some peculiarities in the life cycle of locusts, notably the egg stage, being the shortest in the tropics in contradistinction to its being the longest in the temperate regions, make it appear that the adult stage might be the most suitable for control. No control which is effective and inexpensive has yet been devised for dealing with adult swarms, and so entomologists still adhere to the hypothesis that the hopper stage is best for control operations. It is concluded that some method must be discovered for *killing adult locusts in flight* and not while resting on the ground. Recently King and Ruttledge have been successfully experimenting with finely powdered sodium arsenite under laboratory conditions. The discovery of a tracheal poison whose particles are light and fine enough to float in the air would, in Mr. Uvarov's opinion, go far to solve the problem. A low-speed aeroplane, perhaps of the autogyro type, fitted with suitable dusting apparatus, would be necessary.

Mr. Uvarov stresses the need for the collection and co-ordination of reports on the occurrence and movements of locusts in all the affected countries of which the present survey gives the preliminary results. The analysis of such reports over a long period concerning the breeding and migration in relation to climatological data would be invaluable. Furthermore, emphasis is laid on the necessity for intensive investigations on the actual conditions under which locusts exist. Finally, he states that the need for pursuing the campaign uninterruptedly over a period of years is of paramount importance.

Huxley Memorial Lecture, 1933[1] **(T. G. H.)**

If the lead given by Huxley had been followed, our present condition would not be as it is. "The portents that face us are terrible—the state of blind ignorance in all countries. We have gained vastly in knowledge but not in *Wissenschaft*: the business of learning and knowing, especially of learning how to use knowledge. We need to

[1] *Our Need to Honour Huxley's Will.* By Professor H. E. Armstrong, Ph.D., LL.D., D.Sc., F.R.S., Macmillan & Co., Ltd., London, pp. 34, price 1s.

abandon the use of the word science: no one understands it: the public think of it as something good only for the few, not for everyday use. Once there was a Sunday lecture Society: to-day, we rush off somewhere in a motor-car or dope ourselves with Hollywood. Huxley spoke of science in 1854, in his celebrated definition, as *trained and organised common-sense*—in italics. As there is no *common* sense to train and organise, there can be no science in

' Scientific workers, thus far, have devoted their activities almost entirely to the service of mammon and the money-changers: the chief exception being those who have followed Pasteur, a veritable Christ in our modern world: their use of knowledge, however, has been only palliative, not constructive. Preparation merely for earning a living—technical education—has counted before all things: the making of souls has played no considered part in our policy." In this country this is due to the giving of mere instruction rather than of education. Average school teachers have no imagination, having never discovered anything by themselves, or have learnt to dream: the idol of knowledge must be deposed in the schools, which means that the present race of head masters must be deposed, a change long overdue. "Our Universities are hopelessly technical and professional—they are not calculated to serve the interests of the community, except through the production of craftsmen; they have allowed a century of scientific advance to pass without codifying and co-ordinating the knowledge gained, in such a way as to make it of general avail. The statesman is allowed to grow up and act without any understanding of the world as it is known to 'science.' This condition is a disgrace to all our houses. The London University system, which compels passing in every enforced subject, is a sin against nature: a product of the unthinking mind of the bookman."

The deficiencies in the teaching of biology are due, at any rate in part, to Huxley himself; his lectures hypnotised his students with the basilisk artistry of his words and his exquisite drawings on the blackboard. He was a highly skilled anatomist, but not an experimentalist; "essentially a didactic teacher with a marked tendency to pontificate. Had he been otherwise, more consciously formative and persuasive as a teacher, his influence would have been far greater: he would have secured more than a select following of intimates. Men such as H. G. Wells would have been inspired to engage in higher work than mere literary froth-blowing: made closer students of the boundless beauty of Nature, they would not have projected the impossible as our human future and would have preached a higher morality, especially to women."

But Huxley realised that form and function are interdependent and unless morphology be interwoven with physiology, which includes chemistry and physics, biology can never be a living science; so that, when the new buildings were in being at South Kensington, now called the Huxley Building, Huxley enrolled Thiselton Dyer, Michael Foster, Ray Lankester and Rutherford. Unfortunately this remarkable crew soon became disbanded: "Zoology became recitative—little more than a descriptive catalogue in the hands of Howes, Huxley's successor. Botany swarmed off under Bower and gradually lost count of the living plant. Physiology was never developed—Foster carried the infant into the Fens and there acquired great merit as its nurse: the spice of South Kensington infused, through Huxley, into University College blood, in fact, had far-reaching effects, as it made Cambridge what it is to-day. I witnessed the transformation.

"A great opportunity was lost of founding a simple, general cultural course of general biology: this has never been regained. Such a course is the crying need of our day, especially at Cambridge. Huxley was not an imaginative, formative teacher, in this particular. He definitely showed lack of generalship. He had the tandem in his grip but lacked constructive outlook, the reins were too long, the team too big, too much for him to hold."

Biology was, and is, not the only subject badly taught, chemistry, engineering, and physics are in like case. But there is the other side; the quality of the teacher is appreciated, or debased, by the quality of the taught.

"We have all been too sanguine in the expectation that 'scientific education' can be made palatable to the many. We have vastly over-rated the possibilities and the value of education, in every field: few are really educable to any extent."

This is enough to indicate the trend of the lecture. It is stimulating and provocative and contains much truth tempered here and there by exaggeration.

One minor point: the references to Charles Kingsley are a gratification to the reviewer; the worth of Kingsley as a writer and a great teacher has yet to be generally realised. I remember years ago . . . but no: unlike Professor Armstrong, I have no licence to indulge in irrelevant personal matters.

Adhesives Research (W. B. L.)

The Third and Final Report of the Adhesives Research Committee (H.M. Stationery Office, price *2s. 6d.* net) contains an

account of the researches undertaken since the second report was published in 1926. They are described in three appendices which follow the formal report of the Committee.

Appendix I reviews and extends a previous paper by Douglas and Pettifor (*J. Roy. Aero. Soc.*, 1929, **33**, 91). The work is almost entirely of a practical character and advances considerably our knowledge of glued wood joints. This section of the report should be of great interest to the woodworking industry. (Some theoretical aspects of adhesion in glued wood joints are discussed by McBain and Lee in Appendix III.) As a result of the extensive investigations at the Royal Aircraft Establishment, the simple-lap type of test-piece is recommended for testing the strength of joints in timber with various adhesives. Beech is suggested as the most suitable timber for use in the construction of the test-piece. Suggestions are made for economising timber and for reducing the labour of conducting the multiple tests.

Numerous factors which probably determine the strength of timber-glue joints have been studied in considerable detail. Interesting diagrams showing the influence of density of timber on the strength of the simple-lap joint with a given adhesive have both theoretical and practical interest. The strength is largely dependent upon the species of timber used. For light timbers the strength of the joint increases with increasing density. On the other hand, with very dense timbers the joint strength appears to fall as the density increases. The joint strength is reduced by using weak adhesives when dense timbers are used in constructing the test-piece. If light timbers are used only a slight reduction of strength results.

Experiments were also made with a timber-fabric test-piece and the variations were less than with timber-glue joints. The timber-fabric joint may be of use for certain specialised tests, but the results are greatly influenced by changes in atmospheric humidity.

Appendix II.—The investigations on gelatin are classified as follows: (1) A preliminary investigation on the dynamics of the formation of gelatin from its precursors such as collagen and ossein. (2) The purification of gelatin. (3) The intramolecular changes undergone by gelatin. (4) The methods of analysis of proteins and the separation of their products of hydrolysis. Much of this work has been published in a series of papers in the *Biochemical Journal*, and the general nature of the researches and the chief results obtained are reviewed concisely and clearly in this brief appendix of 9 pages.

(1) was discussed in previous reports of the Adhesives Research Committee.

(2) The method used for the preparation of a firm gel is first

described. The gel is then submitted to electrolysis for several days. A product of low ash content but containing nitrogenous products other than gelatin is thus obtained. (For details see Knaggs, Manning, and Schryver, *Biochem. J.*, 1925, **17**, 483.) The gelatin is then purified by a process analogous to that of recrystallisation. The method may be modified by submitting the gelatin solutions to the action of an electric field by the method of Knaggs and Schryver.

(3) The various intramolecular changes of gelatin are discussed under the following headings: (*a*) Action of cold acids; (*b*) The amino-nitrogen of the hydrolysis products; (*c*) The Anionic and Cationic forms of Gelatin.

(4) Certain treatments of gelatin may alter the protein in such a way that it yields on hydrolysis products different from those yielded by the untreated material. The isolation and quantitative determination of the hydrolysis products is necessary in order to explain such intramolecular changes. This section therefore deals with methods of protein analysis and separation of hydrolysis products. The "carbamate" method is useful for the separation of glycine and has been described in a previous report.

Methods of fractionation of various amino-acids in the form of their copper salts (in certain cases their zinc salts) are described. "Advantage is taken of the different solubilities of the copper salts of the individual amino-acids in certain solvents, particularly water, absolute alcohol and methyl alcohol."

Appendix III.—The researches of McBain and Lee have broken entirely new ground and extended considerably the work of McBain and Hopkins (*Second Report, A.R.C.*) The Appendix contains a theoretical discussion of adhesion phenomena and is well supplied with references to the work of other investigators in this field. About one-half of the work is of a definitely practical character dealing with glues and recognised adhesives. This should be of considerable interest to the large number of industrial concerns using adhesives whether on the large or on the small scale.

Part I of Appendix III is a general survey of the new results. Part II deals with the use of pure chemical substances as adhesives for polished metal and quartz surfaces. Pure chemical compounds may yield "joint strengths" as high as 1 ton per square inch when used for joining optically polished metal surfaces. Part III discusses the adhesion of gums, resins, and waxes to metals, including the relation of joint strength to film thickness. This should be of interest in the lacquer industry. Part IV deals generally with the mechanical properties of adhesives and similar and closely related materials. The earlier method of determining the tensile strength

of free films of glues has been elaborated by the use of the latest form of the Schopper dynamometer, fitted with Alt recording drums, for a constant rate of loading. The importance of rate of loading and humidity is emphasised. Improvements in the technique for the preparation and testing of glue films are described. Typical and significant data are presented for the mechanical properties of a large number of adhesives and adhesives with added substances. The observations emphasise the practical importance of "deformability" of an adhesive. Stress-strain relations are included. Part V deals with Adhesion in glued wood joints. This contains a discussion of "mechanical" and "specific" adhesion. Part VI summarises the work on solvents and swelling agents for organophilic adhesives.

The upper limit for the effective range of molecular attraction given by McBain and Lee, p 108, is equivalent to a range of the order of a few millionths of an inch. This is of the same order of magnitude as the mean thickness of the usual "wringing" films between optically polished metal or glass surfaces. It is likewise of the same order as the accepted older ranges of classical physics. (The recent work of Staudinger relates to the special case of *macro-* [*long chain*] *molecules*).

Hospital Lighting (S. K. L.)

Illumination in a hospital is evidently a most important subject, and one which has to be treated from several view-points, hygienic, scientific, economic and psychological. The problems of hospital lighting are discussed in a paper by F. C. Raphael, Consulting Electrical Engineer at St. Bartholomew's Hospital, in *The Illuminating Engineer* for May 1933, pp. 118–28. A high degree of illumination is not required in a hospital ward. Restful lighting calls for a low intensity, and, in order to be cheerful, "flatness" must be avoided. The present lighting arrangements at St. Bartholomew's Hospital have received a great deal of thought. At first sight the layout would appear to be old-fashioned, but there is no doubt that it meets the requirements better than the usual modern form of lighting such as is used in an office.

Over each bed in the ward is a wall bracket carrying a 25-watt opal bulb in a satin flint glass shade. Similar shades with 100-watt bulbs are suspended from the ceiling along the gangways at a height of 8 feet The walls are coloured medium cream with a fairly matt surface. With all lights on, the illumination in front of a patient's head is 3·7 foot-candles. Supplementary illumination over any bed is provided by a floor standard carrying a 25-watt lamp and its

shade on a universal bracket. For the examination of cavities the surgeon is provided with a 15-watt hand-lamp. The ward lamps, with special exceptions, are switched over to a lower voltage supply after 8 p.m. so that only dim light is available.

The most exacting requirements are met in the operating theatre. A shadowless lamp is a *sine qua non*. A number of types have been developed, including a ring of about 20 lamps, which gives excessive heating, an arc lamp outside the theatre with a large number of mirrors in the theatre to reflect the light on the table, and the scialytic lamp. The latter, of French origin, is probably the most popular. A large cupola, up to 3 feet in diameter, contains a number of plain glass mirrors built up on a truncated cone to reflect the light from a centrally placed 100-watt lamp and dioptric lens. Modified forms have been introduced by various makers. The remainder of the operating theatre is lighted by wall brackets designed for ease in dusting and washing. The colour of the walls is important. In three of the theatres at St. Bartholomew's Hospital the colour has been changed from cream to green at the surgeons' requests. Some surgeons, however, prefer brighter walls. Green towels to surround the patient have been substituted for white towels to reduce the disturbing reflection. Emergency lighting in the operating theatre is provided by three auxiliary 40-watt lamps within the shadowless lamp, connected to a separate battery supply.

For the education of students, a scialyscope has been developed. Instead of crowding round the operating table, the students sit in an adjacent room and view on a one-metre diameter screen a magnified image of the actual work being done on the table. This is accomplished by a simple form of camera construction, the objective lens being vertically above the operating table. A very large scialytic lamp is required for satisfactory operation.

Miscellanea

The honours list published on the occasion of the King's birthday included the following names. *K.C.B.:* Dr. G. F. Hill, principal librarian of the British Museum. *Knights Bachelor:* Dr. G. C. Clayton, president of the Institute of Chemistry; Dr. R. H. P. Crawfurd, registrar of the Royal College of Physicians, London; Dr. W. S. Duke-Elder, ophthalmic surgeon; Dr. M. O. Forster, recently director of the Indian Institute of Science, Bangalore; Mr. R. S. Pearson, director of the Forest Products Research Laboratory. *C.B.E.:* Mr. V. E. Pullin, director of radiological research, Royal Arsenal, Woolwich. *M.B.E.:* Mr. W. N. Winn, botanist, Royal Botanic Gardens, Kew.

Sir Richard Gregory has been elected a fellow of the Royal Society under the Statute which provides for the admission of "persons who, in their opinion, either have rendered conspicuous service to the cause of science, or are such that their election would be of signal benefit to the Society."

Professor F. G. Donnan has been elected an honorary member of the Bunsen Society.

Professor William A. Bone has been awarded the medal of the Society of Chemical Industry for his work on combustion.

Dr. R. A. Fisher, F.R.S., has been appointed to succeed Professor Karl Pearson as Galton professor of Eugenics in the University of London.

We have noted with great regret the announcements of the death of the following well-known men of science during the past quarter: Dr H. D. Arnold, of the Bell Telephone Laboratories, U.S.A.; Sir Walter Morley Fletcher, secretary of the Medical Research Council; Dr. E. E. Fournier d'Albe, physicist and scientific journalist; Professor V. Goldschmidt, of Heidelberg, mineralogist; Professor H. G. Greenish, formerly professor of pharmaceutics to the Pharmaceutical Society of Great Britain; Professor J. W. Hinton, professor of physics, University College, Colombo; Dr. Leonard Huxley, author and editor; Mr. H. R. A. Mallock, F.R.S., engineer; Dr. N. U. Meldrum, biochemist; Sir Ernest Moir, engineer; Dr. J. Schmidt, of Stuttgart, organic chemist; Dr. O. Stapf, formerly keeper of the herbarium and library at the Royal Botanic Gardens, Kew; Col. J. C. B. Statham, naturalist and explorer.

Dr. H. E. Ives will deliver the Thomas Young Oration to the Physical Society on October 6. He has chosen as his subject the application of Young's three-colour theory to the artist's palette. It is not generally realised that the pigment primaries are the colours obtained when red, green and blue are subtracted from white. These are turquoise (minus red), crimson (minus green) and yellow (minus blue); pigments of these colours, having proper spectral characteristics, together with white, will mix to give all the variations of saturation and hue which the artist requires. Recent advances in the dye industry have provided pigments which satisfy the spectral conditions well enough for practical purposes and Dr. Ives will show pictures painted with them on the occasion of his oration.

The article "Recent Advances in Physics" contained in this number of SCIENCE PROGRESS describes how temperatures as low

as 0·27° K. have been obtained by the adiabatic demagnetisation of cerium fluoride. Continuing their experiments at Leiden, de Haas and Kramers have now reached a temperature only 0·085° C. above the absolute zero.

The International Temperature Scale is defined in the range 660° C. to 1,063° C. in terms of the indications of a platinum, platinum—10 per cent. rhodium thermocouple calibrated at the freezing points of silver, gold and antimony. Comparisons of the scale at the National Physical Laboratory, the Reichsanstalt and the U.S. Bureau of Standards are in agreement at the gold and antimony points but differ by 0·5° C. at the silver point. The reason for this difference has been investigated by Roeser and Dahl, and their methods and conclusions are described in the *Journal of Research* of the Bureau of Standards (May 1933). They find (*a*) that the presence of only 0·068 per cent. of copper in the silver is sufficient to lower the freezing point by 0·5° C., (*b*) that the F.P. of silver saturated with air at 76 cm. pressure is 11·2° C. lower than that of the same silver protected from the access of oxygen, (*c*) that if the silver is saturated with oxygen at 76 cm. pressure the F.P. is lowered by 22·6° C., (*d*) that the F.P. *in vacuo* is only 0·005° C. *lower* than that at atmospheric pressure, and (*e*) that the F.P. of silver melted in a graphite crucible with a graphite lid, but otherwise exposed to the atmosphere, is the same, within 0·05° C., as that of the same silver *in vacuo*.

In a paper in the June number of the *Journal of Research* Henning and Wensel describe their measurements of the freezing point of iridium. Using a very pure sample of iridium prepared by Dr. Wichers and believed to contain less than 0·01 per cent. of metallic impurities they find the freezing point to be 2,454° ± 3° C. Their mean of 4 very consistent values based on the gold point (1,063° C.) was 2,453° C., while 4 slightly less consistent results based on the platinum point (1,773·5° C.) gave 2,455° C. They therefore conclude that the freezing point of platinum is probably lower than 1,773·5° C. and give it as 1,773° ± 1° C.

The *Bell Laboratories Record* for July contains a short description of an electric watch timer which enables a jeweller to regulate a watch to the maximum of its time-keeping efficiency in ten minutes instead of the ten days now required for a really careful adjustment. When the watch is placed in a compartment of the instrument an image of the balance wheel is reflected in a mirror and its period is compared stroboscopically with that of a flashing lamp. The timer

can then be adjusted so that the gain or loss in seconds per day is read off directly on a dial.

The *Annual Report* of the Imperial Institute for the year 1932 shows that the work of the Institute has grown very considerably in the last six years while the number of visitors to the galleries exceeded a million. There is unfortunately no detailed financial statement in the *Report*, but it appears that grants from Governments within the Empire have fallen by 35 per cent. since 1929 and that the generosity of Sir Benjamin Drage and of Lord Wakefield and his Company has alone made it possible to keep the work going. This work was varied indeed. It included the examination and sale of trial consignments of manilla hemp from St. Vincent and of tea from Nyasaland ; advising Madras as to the possibility of marketing egg products in England and the United States, Tanganyika concerning the export of beeswax, and Jamaica as to sale of Muscovy ducks' feathers from the Cayman Islands. One investigation, it may be hoped, was a little unusual. A British firm manufacturing photographic goods found that plates exported to Japan had been removed from their boxes and mud substituted for them. The mud contained rice husks and was of a type suggestive of a Pacific origin, so that it was fair to conclude that the theft took place in Japan !

The *Report of the Food Investigation Board* for 1932 (H.M. Stationery Office. Price *5s.* net) reviews in its 300 pages the important work carried out under the Department of Scientific and Industrial Research directed to the improvement in quality and prevention of wastage in foodstuffs by improved methods of handling and storage. Many of the results obtained are of very great interest and we regret that space will not permit reference to more than two or three of them. Experiments dealing with the effects of substances given off as vapour during the ripening of fruit have shown that ripe apples placed among potatoes retard sprouting while the growth of young pea seedlings and other seeds is delayed or distorted by exposing them to air which has passed over ripe apples. The substance poisonous to the seedlings is present in very small quantities (about one part in 30,000). Although it has not been isolated in sufficient quantity to allow a complete chemical identification, evidence points to the active substance being either ethylene or a body of a similar nature. The remarkable fact has emerged that although the growth of the seedlings is prevented their rate of respiration is unchanged. Apples and other fruit after being gathered are, of course, living

bodies breathing out carbon dioxide. One secret of a long storage life is to keep their respiratory activity low, that is to make them live a quiet life and breathe slowly. In the storage life of all fruit there comes a time when a change takes place. The respiratory activity rises suddenly for a short time, falling again later. This change in the apple's life is called the climacteric. Experiments recorded in the *Report* show that the development of the active substance in apple vapour coincides with this climacteric change and is not present before it has taken place. Apple vapour from fruit which has passed through the respiratory change immediately introduces this climacteric change in other fruit.

The climacteric change also occurs in tomatoes and in bananas. The yellowing of the skin and the softening and the sweetening of the flesh of a banana all take place after it has passed through the climacteric change. The active substance given off by apples has been found to hasten the ripening of green bananas and young apples. It is hoped that the study of the effects of "apple air" on apples and other fruit and the influence of the climacteric changes may lead to a clearer understanding of many of the diseases occurring in fruit which constitute serious practical problems in its storage and handling. The internal browning of apples, for example, is associated with too low a temperature while passing through the climacteric. The development of superficial scald—browning of the skin—appears to be determined during this critical period, which also seems to be connected with the injurious effects of too much carbon dioxide in the atmosphere of the store.

Another section of the *Report* deals with various problems connected with meat. In ordinary air chilled beef can be kept in store for one month, at the end of this period it deteriorates very rapidly. Experiments show, however, that in air containing 10 per cent. of carbon dioxide the storage period is doubled, and if economical means can be devised for maintaining this concentration of carbon dioxide in the refrigerated hold of a ship, export of chilled beef from Australia and New Zealand would be practicable. The solution of this problem would also render it possible for us to obtain chilled pork from the same countries.

Work on fish has resulted in the design of a kiln for the smoke-curing of finnan haddocks and kippered herrings in which the heat required for the cure is provided by electrical heaters while sawdust smoke is produced outside the kiln in such a way that its temperature and humidity when blown into the kiln can be regulated. Fish cured in the new kiln are cleaner and have a better flavour than those

cured in the usual kiln where burning sawdust serves to provide both the heat and the smoke.

Agricultural students and research workers will welcome the new *Empire Journal of Experimental Agriculture* whose first quarterly number appeared in April 1933. It has a strong and representative Editorial Board, and is published by the Oxford University Press. The annual subscription is £1 post free.

Fundamental scientific investigation in the agricultural sciences has greatly increased in Great Britain and the Empire since the war, and the space of the older *Journal of Agricultural Science* (C.U.P.) is now fully occupied with these results. The technical and practical applications, and the highly important studies of the effects of different soils and climates on these applications, have therefore received little general publicity: in the main the results have been recorded in Departmental publications which necessarily have a limited circulation. The new journal will provide an outlet for such papers and will thus enable workers in any part of the Empire to become quickly acquainted with investigations conducted in other regions. The contents of the first issue illustrate this point very well. There are two papers on soil profile and surveys: one deals with Western Canada, and the other with Cyprus. Another pair of papers deal respectively with the influence of management on the botanical composition of grassland, and the development of hay-making machinery.

ESSAY REVIEWS

BETWIXT AND BETWEEN. By A. S. C. Lawrence, Ph.D., Department of Colloid Science; and F I G Rawlins, M.Sc., F.Inst.P., University Research Assistant in Crystallography, Cambridge. Being a review of "**Liquid Crystals and Anisotropic Melts.**" A general discussion organised by the Faraday Society. [Pp. 205, with 11 plates.] (London: Gurney & Jackson, 1933. Price 12*s*. net.)

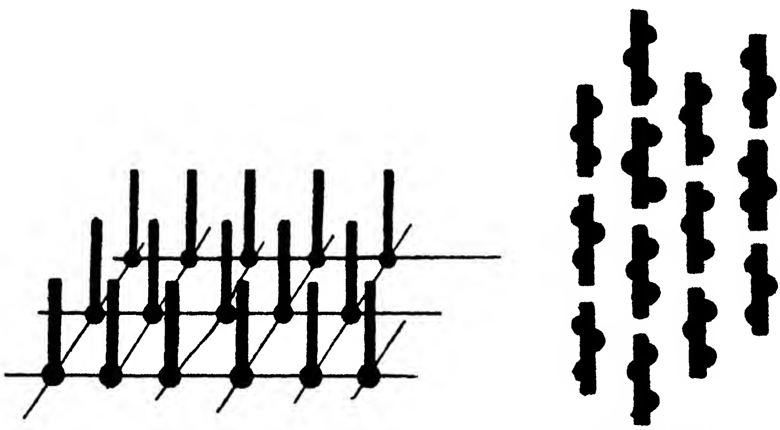
Liquid crystals are not real crystals nor are they really liquid. Having made this anticipatory recantation, I shall feel justified in using the name, it is indeed necessary at present. It is curious that so little attention has been given to the subject, especially in this country. Perhaps it is for the same reason that the mechanism of crystal growth has been ignored by crystallographers who work from the opposite direction—determination of the structure of crystals ready-made by Providence (or a chemist) Microscopic examination of liquid crystals in polarised light has given much information of their structure [1]; and the phenomena observed are remarkable for their unique beauty of colour and pattern which attract one irresistibly. It is unfortunate that demonstration on any scale is so difficult. The optical properties responsible are complex and peculiar, but that is just one more reason for interest. The monumental work of Friedel along these lines has established the existence of two types of liquid crystal, each with characteristic appearance due to its structure. How fundamental this difference is has become clear with increased knowledge of molecular individuality.

The inadequacy of the name "liquid crystal" is, actually, a reason for its use since, in the present state of our knowledge of these substances, new nomenclature is no more than evasion of recognised difficulties by substitution of meaninglessness of unknown extent. Here the word "*mesoform*" is used to denote any state of aggregation intermediate between liquid and solid. The aggregation may be partly regular or completely irregular; it may appear on passing from a melt to a solid or from solution to solid. Most

[1] See plate facing p. 345.

liquid crystals are examples of the former, but a few are known sufficient to show that quite similar types can appear from solution.

For classification, Friedel's names are generally used. These are *smectic* and *nematic*. All the substances forming liquid crystals have rod-shaped molecules. These lie side-by-side in both meso-forms but with the essential difference that in the smectic they are held together in sheets [1] which slide freely over one another, whereas in the nematic there is no such stratification and the molecules have the less regular imbricated arrangement shown. It is clear that a smectic substance has a regular periodicity which gives the simple X-ray diffraction pattern from which the actual thickness of the sheets can be calculated. There is no such result from the nematic packing. The nature of the molecules forming the two types of

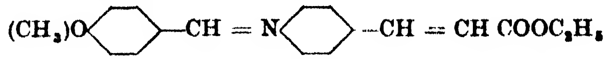


Smectic layered　　　　Nematic imbricated

mesophase differs in the way indicated in the diagram. For the smectic, all that is required is a long molecule without side chains or substitution and with a polar group at one end. These hold the molecules into the necessary sheets. In molecules in which the lateral adhesion is not negligible, the end polar group must not be too active in associating, else the liquid will pass directly to solid. For this reason an aromatic substance, such as *p*-azoxy-benzoic acid, forms no mesophase until esterified. The soaps are the simplest smectic substances. Nematic are less simple; they are rod-shaped but with several groups of quite moderate associating power such as the Azoxy, the N = CH and conjugated double bonds. This simple picture makes it clear that transition from one to the other mesoform is unlikely to occur often. In fact, the smectic is closer to the solid with a layer lattice and the nematic is closer to its

[1] See plate, Fig. (*b*).

liquid than the two mesoforms are to one another. A good example of the rare class which passes through both mesoforms is Ethyl-anisal-amino-cinnamate



which quite obviously has the requirements for both types separately.

People who habitually travel by express trains regard those which stop at every wayside station and halt as freaks. How far is this the attitude towards liquid crystals ? Altogether some 2,000 such substances are known, so that the prospect of so many freaks is alarming unless we can show that they are closely related to those molecules which are more direct, if less enterprising, in their phase change, solid–liquid It might be argued though that the conventional way is the more enterprising one since it is a short cut. On these lines a formal statement of the behaviour of liquid crystals can be made. A solid is rigid in three dimensions , the smectic in two and the nematic in one. On heating, melting occurs in the three dimensions in turn , the three different melting-points being the temperatures at which the three vectorial forces of adhesion are overcome by thermal agitation. This formal statement, though, is not really so accurate as the picture already drawn from chemical considerations.

Nevertheless, it does draw attention to the need for consideration of energy changes during the phase change, liquid–solid, and to the fact that molecules will follow the change which requires the smallest energy change.

The basic observation upon liquid crystals is that two or more melting-points are possible , from solid to mesoform, which is from solid to a cloudy liquid ; from one mesoform to others, if existing ; and then the final melting point to a clear liquid. This cloudiness of mesoforms in bulk is important, for it suggests some sort of secondary structure. Just as marble is opaque because the transparent crystals of which it is composed have no common orientation, so mesomorphs are cloudy because of their optical heterogeneity. In smectic and nematic melts the type of optical heterogeneity is different. Smectic have a focal conic structure [1] which prevents a ray of light from passing straight through. Nematic, however, are better pictured as *micro-liquid-crystalline* and are therefore more closely analogous to marble. Optical examination of thin films of these substances is complicated, particularly for nematic ones, by the curious fact that their optical heterogeneity is lost to a great extent in a thin film owing to the influence of the glass surfaces

[1] See Fig. (d).

enclosing it: an influence which seems to extend into the mesoform to a distance of the order of a tenth of a millimetre. This is not a specific effect of the glass since often it has no orientating effect and the mesoform appears dark between crossed nicols. All observations recorded are that both smectic and nematic substances are uniaxial; but there are reasons for believing that biaxial mesoforms do exist. Nematic melts spread on cleavage surfaces of most crystals, but smectic only on those whose lattice corresponds fairly closely with the packing of the molecules in their layers. All the properties of smectic follow from this stratified structure. Their characteristic *focal conic*[1] texture is a direct consequence of the tendency to preserve it in the face of discontinuities due to different orientations. How this comes about is described clearly and briefly by Sir W. Bragg in the report. Their molecular attraction is different in different directions, so that drops are not spherical and on certain surfaces show the curious phenomenon of spreading in specific directions in rectilinear bands Thus the structure of smectic mesoforms has been worked out from the optical and X-ray examination and the bulk properties are quite unknown. With nematic, it is otherwise; although their optical properties have been used indirectly to differentiate them from smectic, most of our information has come from examination of their physical properties in bulk.

At the recent discussion organised by the Faraday Society, Continental workers brought their individual view-points to stimulate those workers in this country who are sufficiently interested to see the possibilities of the subject and its wide importance. It emphasised the lopsidedness of the approach to the subject, since the newer work is on the bulk properties and therefore mainly concerned with nematic substances. The report of the meeting contains a number of experimental approaches which are direct and straightforward. A magnetic field has little effect upon smectic substances owing to the persistence of the layer arrangement, but orientates nematic. The orientation is followed easily by the variation of opacity. In the field, it decreases as the optic axes assume a common direction; and this occurs with a field strength quite insufficient for orientation of single molecules. The explanation is that each unit of what I have previously described as *micro-liquid-crystalline* is such that it is orientated as a whole by the field. These units have been called "swarms."

Their ease of orientation requires that, in the swarm, molecular dissymmetry is intensified—that all the molecules in each swarm have

[1] See Fig. (*c*).

a common orientation. The orientation of the swarms themselves is random in absence of external forces—hence the opacity. This additive effect differentiates nematic swarms from the *cybotactic aggregates* which are supposed to exist in isotropic liquids which diffract X-rays. These aggregates are not affected by external forces with the ease with which those in nematic melts are, so that the cybotactic aggregates must be built up with a random internal arrangement. In each cybotactic aggregate, therefore, molecular dissymmetry is cancelled out instead of leading to the additive effect of the nematic swarm. The dissymmetry of a swarm is only the sum of that of its constituents, but this is greatly exaggerated in its effects by the reduced kinetic activity, which is the disorientating factor acting against any externally applied force. It may be noted here that there is no analogy between these swarms and colloid micelles (except perhaps for a vague correspondence of dimensions). A colloid system requires two components and an interface solute/solvent so that aggregation and, later, adsorption occur to lower the interfacial energy. It is suggested that the swarm contains about 10^5 molecules so that it will have a diameter of the order of 1μ This figure is supported by measurements of the movement of ions in the mesoform and by the *relaxation time* method Orientation in an electric field occurs, as in the magnetic field, at a strength insufficient to orientate single molecules. If the dielectric loss is measured in an alternating field for various frequencies, it will be constant until a frequency is reached such that the time taken by orientation of the units, delayed by viscous resistance, is of the same order as the frequency interval . this gives a measure of the particle size.

Qualitative support is also given to the swarm theory by observations on the viscosity of nematic melts. It has always been recognised that nematic substances are characterised by their fluidity, whereas smectic are much more viscous—except where one layer moves over the next.[1] Further, the viscosity/temperature curve shows a sudden large increase over a range of 2° or so below the temperature of transition, nematic→liquid. Above the clearing point, the curve becomes normal again but with a slope different from that over the nematic temperature range below the peak value. More recently, it has been shown that the viscosity is anomalous over the whole nematic range ; and that the anomaly of flow corresponding to the peak observed " viscosity " is different from the anomaly at lower temperatures. Anomalous viscosity is due, in all other systems examined, to large aggregates so that the swarms can be considered responsible. This clearly means that their per-

[1] See Fig. (*b*).

sistence and objective reality are such that mechanical disturbance has little effect upon them. The swarms do not begin to break up until close to the melting-point so that the peak in the viscosity/temperature curve and its separate anomaly of flow are both due to turbulence accompanying the sudden dispersion of the swarms in this small temperature range. It is clear that the evidence for the swarm theory by these various methods is direct and in good quantitative agreement. It may then be asked why the swarms exist. This has been considered from the starting-point of density fluctuations; that is, as a problem in packing, which reminds us of the original criteria of the molecules forming liquid crystals.

An "isotropic" liquid may have a structure. This, whether existing only just above the melting-point or over a wide temperature range, is different from the structure of liquid crystals. These exist as definite states with sharp transition temperatures and characteristic properties, some of which have been described. The nematic mesoform is very close to the liquid, but it is not surprising that the cybotactic structure differs from it, since we have seen how narrow are the limits of molecular constitution permissible in liquid crystal formation. Lack of the necessary symmetry not only makes it ineligible for a mesoform but also affects its so-called random arrangement in the liquid state. The step-by-step transition from liquid to solid is essentially one of small changes of internal potential energy at each step. Those factors preventing *mesoformation* are also the factors which lead to supercooling and other signs of a large change of internal energy in the single-step change of state. From this view-point the change liquid–smectic–solid is clear and straightforward. On the other hand, the transition nematic–solid may entail a large energy change and result in formation of an intermediate solid form which is metastable and which then passes to the normal crystalline arrangement.[1] The energy change nematic→metastable, is small. The solidification of the nematic mesoform seems to be characterised by imbrication of the molecules (as shown in the diagram at the beginning) which distinguishes them sharply from the layer lattices to which smectic substances pass.

This idea of a small difference of internal potential energy between one form and the next explains the extraordinary depth to which the influence of the surface or interface extends. The influence of the glass surface causes solidification of the surface layer for some distance into the liquid, the latter acting as if under the influence of an external force; as it actually is. It is due to these layers that discontinuities of a mesoform can be preserved when the preparation

[1] See Fig. (*d*).

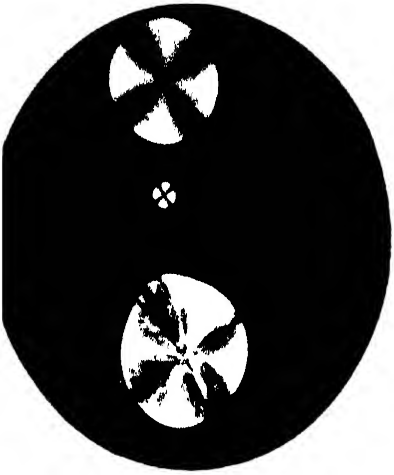


Fig. (a)

Fig. (b)

Fig. (c)

Fig. (d)

is melted so that, on cooling, they reappear in the same places. There is some indication that these surface layers have fairly definite melting points of their own some degrees higher than the bulk value. Heating above this point would destroy, of course, all discontinuities other than those due to specific action of the glass surfaces. Finally, the pseudo-pseudomorphism of liquid crystals is explicable, for, if the re-arrangement in passing from, say, mesoform to solid, is slight, then it is to be expected that the external form will remain unchanged although this may not be a regular geometrical one. Irregular structure due to this cause can be seen in Figs. (*b*), (*c*) and (*d*).

One cannot expect a report of this kind to be entirely consistent since it deals with work carried out with a number of different viewpoints. One of the purposes of the meeting was to see to what extent accommodation of apparently conflicting views was possible. The dual approach—optical methods for the smectic and bulk physical properties for the nematic—has undoubtedly led to false perspective on occasions but, nevertheless, is justified to a great extent by the really definite results obtained. There are still optical properties to be explained, particularly those of cholesterol compounds; and there are still physical properties to be observed. The value of the meeting and the report of the discussions cannot be assessed now, it will depend upon the extent to which their undoubted stimulation leads to further research in the subject and general interest in the phase change, liquid$\rightarrow$solid in the light of liquid crystals.

The plate shows photomicrographs, magnification 50, taken in polarised light with Nicols crossed Isotropic liquid, therefore, appears dark while liquid and solid crystals are bright.

(*a*) shows anisotropic spherulites, one of which is solid and the other two liquid.

(*b*), (*c*) and (*d*) are all being heated by a hot wire. In (*d*) it crosses the field but in (*b*) and (*c*) it is just outside on the left side so that there is a temperature gradient across the picture falling from left to right.

(*b*) shows liquid, smectic and solid in a drop on a glass plate. The surface, instead of being a smooth curve as in an ordinary liquid, is stepped; each smectic layer sliding over the next freely. Expansion of the hotter part of the liquid has so slid the layers over one another that their spacing is much closer there than in the cooler part of the specimen on the right side. The edges of each layer show the focal conic structure characteristic of the smectic mesoform.

(*c*) shows the characteristic appearance of a smectic mesoform—focal conic structure—between the hotter liquid and the cooler solid. The mesoform looks to be in two parts owing to the cooler part being a pseudomorph of the solid from which it was formed by heating. Baby focal conics delineate, in this region, the lines of discontinuity originally in the solid and whose continuation can be seen in the still solid part.

(*d*) is a nematic melt. A small amount of liquid is present around the hot wire; and, from each side, solid is growing. The disorderly structure in the nematic part is pseudomorphic of the solid crystalline mass from which it was melted. The two solid parts are clearly at different distances from the hot wire, which means that their melting-points are different. In fact, the one on the right is the metastable form while the other is the common stable one.

THE CATHODE RAY OSCILLOGRAPH IN RADIO RESEARCH. By R. A. WATSON WATT, J. F. HERD, and L. H. BAINBRIDGE-BELL. [Pp. xvi + 290, with 17 plates.] (London: H.M. Stationery Office, 1933. Price 10s. net.)

THE extreme usefulness of the cathode ray oscillograph in high-frequency work lies in the fact that it has no natural period of its own, so that there is no need to employ those arrangements for producing critical damping which are so complicated when mechanical oscillographs are used. Also, since there is no resonance effect, sensitivity does not change with frequency The highest frequency at which the oscillograph will work satisfactorily is determined by the time taken for the electrons to pass through the space between the deflecting plates, and with modern oscillographs is of the order of 10^7 per sec. A difficulty is encountered when working at frequencies above about 10^5 per sec., due to the fact that the focus of the electron jet is disturbed, thus causing the trace on the fluorescent screen to be broadened. In radio work trouble due to this effect can usually be avoided by using a frequency-change amplifier so that the frequency applied to the oscillograph is less than the original radio frequency under investigation.

Probably the most useful characteristic of the cathode ray oscillograph is that, unlike mechanical oscillographs, deflections in two directions at right angles can be obtained, so that the spot can respond simultaneously to two independently varying potential differences. In one type of application of the oscillograph one of the deflections may take the form of a " time base sweep " so that the other deflection is plotted on the screen as a function of time. This is much more convenient than the rotating mirror or falling plate type of time base which has generally to be employed with mechanical oscillographs. In another type of application two electromotive forces of the same frequency are made to produce the two perpendicular deflections, and from the resulting ellipse the phase and amplitude relations can be deduced. This method of use is particularly convenient when the phases and amplitudes are varying rapidly, the nature of the variations can then be followed by watching the changes in shape of the ellipse on the screen.

These general methods of using oscillographs have been known since the days of the Braun tube, in which the electron jet was produced by an accelerating potential of about 2,000–3,000 volts. With this tube it was necessary to put the photographic plate inside the evacuated tube in order to obtain records of an instantaneous pattern on the screen. If the spot could be made to retrace its path

so that a steady pattern was obtained, then it was possible to obtain photographs from outside the tube by using a long exposure. In recent years a much improved form of oscillograph has been produced, the characteristic features of which are :—

(*a*) it may be run on a potential as low as 350 volts ;

(*b*) it contains a Wehnelt cylinder whose potential is adjustable for purposes of focusing ;

(*c*) a screen has been developed which gives a light very suitable for photography outside the tube

With the newer form of tube it is possible to photograph the trace left by a transient which is so short that the speed at which the fluorescent spot moves over the screen is 20 km. per sec. For this purpose the potential has to be raised to about 3,000 volts. For photography of slower transients, or of stationary or quasi-stationary patterns, or for visual observations, a much lower potential may be employed, with corresponding increased voltage sensitivity of the tube.

Radio workers all over the world have always been quick to make use of each development of the cathode ray oscillograph, and the workers at the British Radio Research Station of the Department of Scientific and Industrial Research were amongst the first in this country to realise its possibilities Since 1923 when they started using it, at the suggestion of E. V. Appleton and R. A. Watson-Watt, to delineate the wave form of atmospherics, they have made increasing use of it in all their work on the propagation of wireless waves, and this book reveals the great skill and ingenuity which have been exercised in applying the oscillograph to elucidate the nature of the electromagnetic field at a receiving point. It is made quite clear in the Preface that the authors are " not concerned to claim originality or unique merit for the assemblages of known devices which they describe." Their account includes descriptions of arrangements and circuits which have originated with workers all over the world, as well as those which have been developed at the Radio Research Station. On the other hand no applications are described which have not been used either at the Radio Research Station or by workers closely associated with that station. Since the work of the station covers all branches of research on the propagation of waves, it follows that this book is a very complete summary of the instrumental side of this kind of research ; it is not concerned with the results of the experiments or with their interpretation in terms of the ionosphere.

The applications of the oscillograph which are here described are concerned either with determining the temporal variations of electromotive force at a receiving point, or with comparing the

phases and amplitudes of electromotive forces induced in different receiving aerial systems. Under the first type of application may be grouped the determination of the wave form of atmospherics, and the recording of the time interval between the arrival of a short signal directly along the ground, and after reflection at the ionosphere, according to the method of Breit and Tuve. Remarkable ingenuity has been displayed in the production of time-base deflections for use with this type of investigation. " Linear " time bases produced by a flashing neon lamp, or by a leaky-grid " squegging oscillator," have been in use with oscillographs for some time. This type of time base is specially useful, since, in virtue of the fact that it is a " relaxation oscillation," it is readily synchronised with any periodic electromotive force whose wave form is required. Several interesting modifications of this have been produced for special purposes ; in one a series of sweeps are caused to occur underneath each other so that the transient appearing on the first sweep is not confused with one appearing on the second or third sweep. Another type of time base is driven from the A.C mains, and has been arranged to have the form of a circle or of a spiral ; in a third arrangement a transient, whose wave forms it is desired to delineate, automatically produces a single time-base sweep for the delineation of its own wave-form.

When it is desired to use the oscillograph as a " voltage comparator " to compare the phases of two radio frequency electromotive forces, it is usually desirable to amplify each electromotive force separately before applying it to the plates of the oscillograph. For this purpose a frequency-change amplifier is employed and use is made of the fact, first pointed out by Merritt, that if the heterodyning oscillation is fed into the two amplifiers from the same local oscillator, then the phase relations between the final electromotive forces are the same as those between the original radio frequency electromotive forces. Apparatus depending on this principle has been developed to a very high pitch of perfection at the Radio Research Station, and its construction and use is described in detail in the book

The voltage comparator is generally used with two aerial systems to investigate the nature of an arriving wave. Thus it is used in conjunction with two perpendicular loop aerials with a common axis for direction finding in the case where the atmospheric ray is negligible compared with the ground ray, and for determining the polarisation of down-coming waves in the case where the ground ray is negligible ; in conjunction with two similar spaced aerials it is used for direction finding in the horizontal or vertical plane,

according to the orientation of the aerials and the predominance of the ground ray or atmospheric ray. The crossed loop direction finding apparatus has been made up into a form suitable for commercial use on board ship.

Some of the most interesting applications from the point of view of ionosphere investigations have arisen by combining the voltage comparator with the pulse method of Breit and Tuve, so that the different reflected signals are separated in time from one another and from the ground signal. The crossed loop apparatus can then be made to give a direct picture of the state of polarisation of the individual echoes, or it can be made to give a direct reading of the direction of arrival of the ground wave, even in the presence of strong down-coming waves. This latter application has only recently been reduced to a state where it is convenient for commercial use. It undoubtedly has great possibilities and should be used much in the future. It is a typical example of the way in which the fundamental scientific work of the Radio Research Station is constantly being applied to useful ends.

In connection with the description of much of this apparatus the authors use the very unpleasant expression "to common," meaning "to connect together electrically." Whenever two points of circuits are said to be "commoned" they could equally well be said to be "connected together," and the wording would not jar on the English ear. Since such a large part of the work described in this book is of English origin from its inception, it is unfortunate that phrases should be introduced which make it sound as though they, and hence the work that they describe, have been imported from a country where such slang expressions are common in scientific works.

The book contains a detailed account of all the circuit arrangements which are necessary for the investigations described above, and is liberally supplied with circuit diagrams. It also serves as a very useful practical manual for anyone who has occasion to use a cathode ray oscillograph; the properties of these tubes and the difficulties likely to be met with in practice are dealt with fully, and particular attention is devoted to the problems of photographing the screen image, either on a moving film or by snapshot exposure, or for photography of transients. It is a book which no worker on the propagation of radio waves can afford to be without; with it he will have the ingenuity of the whole of the Radio Research Station at his disposal; without it he will struggle alone, and, if he is very inventive, will probably arrive, after much tribulation, at some of the circuit devices here described.

J. A. R.

REVIEWS

MATHEMATICS

Linguistic Analysis of Mathematics. By ARTHUR E. BENTLEY. [Pp. xii + 315.] (Bloomington, Indiana, Principia Press, 1932.)

WE have here an attempt to examine afresh the basis of mathematics. Although the author differs from Hilbert at many points, his ideas seem in many ways a generalisation of Hilbert's Mr. Bentley wishes to apply the methods of mathematical reasoning to the philosophical basis of mathematics itself and to avoid basing mathematics on the ideas of Aristotelian logic, which he regards as not superior to those of mathematics itself. The idea seems attractive to a mathematician.

The writer seeks to examine not only the mathematical symbols, but also those surrounding forms of expression and assertion through which the symbols are developed, communicated and interpreted. His object is to establish a firm construction for this embedding language. This construction is, in effect, a purification of that language. The purification is presented as one under the control of mathematical consistency itself, a procedure brought forward in sharp contrast to the many efforts to obtain the consistent organisation of mathematics under the control of Aristotelian logic. The influence of Hilbert is at once apparent in this point of view.

The book is written very clearly and, considering the complexity of its subject matter, is eminently readable. The views expressed are interesting; but they have not yet received that full criticism and discussion which is essential before we can tell how good a guide they may be.

E. M. W.

PHYSICS

A Textbook of Physics: Vol. I, Mechanics. By E. GRIMSEHL. Edited by PROFESSOR R. TOMASCHEK, D.Phil. Translated from the 7th German Edition by L. A. WOODWARD, B.A., Ph.D. [Pp. xii + 433, with 487 figures.] (London: Blackie & Son, Ltd., 1932. Price 15*s*. net.)

IT seems to be a growing practice among continental teachers of physics to write comprehensive treatises on their subject. The English incline more towards separate textbooks, or series of monographs. To judge by the number of these four and five volume treatises that get translated into English, there must be an active market for them. One of the latest additions to their ranks promises to run to four volumes; but my present concern is with the first volume only, which treats of mechanics.

Let us start with the incontestable. It is the work of the late E. Grimsehl and it achieved considerable success in Germany, where it ran to at least seven editions. Subsequently edited by R. Tomaschek, it has been

translated into English by L. A. Woodward; it runs to over 400 pages and costs 15*s*. The index alone runs to 9 pages, and the number of figures in the text (I took the trouble to count them) is 487.

Coming to matters of opinion, not all of these figures are very illuminating, *e.g.* the vena contracta on p. 342; the "model of siphon" on p. 327, which is simply a rope thrown over a pulley; or the "block of wood in stable equilibrium" on p. 130. But I like the scholarly touch in giving footnote etymologies of the terms employed, and still more do I like the brief biographical summary whenever a name first occurs.

The work has a curiously composite character, and savours more of "properties of matter" than of "mechanics" as the term is understood in England. The fifth chapter, on Elasticity and Strength of Materials, usually goes into an engineering course, whilst the seventh chapter, with its very interesting and elementary account of crystal structure, is usually reserved for physicists. Throughout the book the mathematical treatment is distinctly elementary; yet very readable accounts are given of gyroscopic motion, of turbines and of aeronautics.

Although we are explicitly told so in the preface, it is otherwise pretty evident that Grimsehl must have been an outstanding teacher, and it is to teachers that I think the book will principally make its appeal. Anyone who has to cover a wide syllabus with students of limited mathematical attainments will find this book an invaluable aid to making his work "live."

It is said that "a large collection of questions from English University examination papers has been added." Can seventy questions, mostly descriptive, be called a large collection? I leave the reader to decide; but picking up a book at random, I find ninety-two after a single chapter in Besant.

F. E. RELTON.

A Textbook of Physics: Vol. II, Heat and Sound. By E. GRIMSEHL. Edited by PROFESSOR R. TOMASCHEK, D.Phil., and translated from the 7th German Edition by L. A. WOODWARD, B.A. (Oxon.), Ph.D. (Leipzig). [Pp. xi + 312, with 225 figures.] (London: Blackie & Son, Ltd., 1933. Price 12*s*. 6*d*. net.)

IT is not unreasonable to expect that a book selected for translation into English from the seventh edition in its original language should be of outstanding merit. Here however is little but mediocrity, and it must be assumed that the *raison d'être* of the translation is to be found in the three other volumes which, with this, constitute the complete textbook. The standard on the whole is that of the English pass degree, but the treatment of the subject matter is very uneven both in its scope and its manner. It might be supposed that some parts of the book have not been revised since the nineteenth century while, on the other hand, there is a long and excellent account of the kinetic theory of matter, a clear and simple discussion of the probability aspect of entropy, a good description of the phenomena associated with coupled vibrations and an excellent section on the practical forms of the heat engine.

Experimental determinations of the mechanical equivalent of heat are limited to Joule's historic experiment, Grimsehl's laboratory apparatus and, of all things, Hirn's collision experiment! (There is, however, a brief description of Callendar's continuous-flow method in an appendix.) Modern repeti-

tions of the Joule-Thomson porous plug experiment are ignored and its application to temperature measurement is not mentioned. There is no mention of any of the experimental methods for the determination of the critical constants of a fluid or for the measurement of latent heat of vaporisation (excepting an unsatisfactory apparatus for steam at atmospheric pressure). Van der Waals' equation is derived in an elementary manner but is not discussed and there is no reference to the reduced equation, the law of corresponding states or the law of rectilinear diameters. Thermal conductivity is called *specific* thermal conductivity—a bad error—and is defined in a manner which the reviewer has been accustomed to deride in his lectures as slovenly. Newton's law of cooling is stated in the following words: "the rate of cooling being directly proportional (within certain limits) to the temperature difference and *to the time*" (our italics).

The section of the book devoted to Heat occupies 188 pages; it is followed by 60 pages on Vibrations and Waves and 36 pages on Sound. Here the treatment is quite orthodox and there is little fault to find, although the "Sound" hardly extends beyond the intermediate syllabus. The book concludes with a collection of data, a collection of problems taken from examination papers set at English universities, and an index. The source of each of the problems is stated, but the abbreviation *Inter* appears to be used both for Intermediate and Internal Final.

The translation is quite satisfactory, there are few slips and the production of the book is all that could be desired.

D. O. W.

Atomic Energy States as derived from the analyses of optical spectra. By Robert F Bacher, Ph D., and Samuel Goudsmit, Ph.D. [Pp. xiii + 562.] (London McGraw-Hill Publishing Co., 1932. Price 36*s*. net.)

Spectroscopists have been busily accumulating data for seventy years or more, and with such success as to render the task of compilation one of almost overwhelming magnitude. It is probable that upwards of 100,000 atomic lines alone have been recorded; the molecular contribution, from band spectra, cannot fall far short of this already, and is likely to exceed it in the future. This immense mass of data is not as it stands of immediate interest to the theoretical investigator It must first be analysed, and the term values, giving the energy states, extracted from it. These are not only of direct theoretical significance but are necessarily, and fortunately, less numerous than the lines themselves. Nevertheless, the task of making a complete compilation of them, even for atomic spectra alone, is a colossal one, requiring not only phenomenal industry but great experience and judgment in addition, since the original sources of the data are very far from uniform either in mode of presentation or in degree of reliability.

The present volume contains tables of energy states for 69 of the 90 known elements, and in most cases for atoms in various stages of ionisation as well as in the neutral state. Altogether there are 233 tables, and in addition to the term values the corresponding configurations, term types and values are listed. Hyperfine structures and g-values are also given where known, and odd and even term values are clearly distinguished from one another. Each table is prefaced by a brief reference to the sources of the data and attention is directed to any unusual or doubtful features. There is an intro-

duction of some twenty pages which presents an admirably concise yet clear survey of modern spectroscopic ideas and notation. Incidentally it contains a very timely warning against the misleading and even incorrect use of the ordinary term notation in cases where the Russell-Saunders coupling conditions do not obtain. A mild protest may be registered against the practice of designating a succession of terms with the same n value a "series" instead of a "sequence." The latter has been customary until recently, and has the advantage of avoiding possible confusion of lines with terms, particularly in the mind of the undergraduate student. It is difficult to see how the change can be justified; the fact that the word "sequence" has a totally different significance in band spectra would hardly provide a sufficient ground.

The book is admirably produced, and is without doubt a notable addition to physical literature. Its value lies no less in the stimulus and assistance which it will give to further investigation than in its convenience and comprehensiveness as a work of reference.

W. E. Curtis.

Objektive Spektralphotometrie. By L. S. Ornstein, W. J. H. Moll and H. C. Burger. Vol. 108–9 of the Vieweg Series "Tagesfragen aus den Gebieten der Naturwissenschaften und der Technik." [Pp. vi + 146, with 75 figures.] (Braunschweig: Friedr. Vieweg & Sohn Akt.-Ges., 1932. Price R.M. 10.80.)

Intensity measurements are steadily becoming more and more important in spectroscopy and students of the subject will welcome this authoritative exposition of the methods developed at Utrecht. The authors frankly confine themselves to those methods of which they have experience, but so much work has been done of late years at this well-known centre of intensity measurements that, in spite of the above limitation, a comprehensive treatise has resulted. Whilst thermoelectric and photoelectric techniques are discussed at reasonable length the major portion of the book is concerned with photographic methods of photometry. Here, a detailed discussion of the phenomena of the photographic plate is given; the variation of the blackening of the plate with intensity, exposure time, wavelength and development is considered at length and the various errors which may be encountered when the photographic plate is used as a scientific tool are examined. Microphotometers are discussed, those of Koch and one of the author's (Moll) being described in detail. The methods of plate calibration are given the prominence they deserve, whilst the features to be noted in the use of the various types of spectrographic apparatus are set down. A chapter worthy of note is that devoted to the absolute measurement of monochromatic radiation.

The book is well produced and the illustrations aptly chosen. The only criticism that can be offered is that the value of the work might have been enhanced by the addition of a short, carefully selected bibliography devoted to work illustrative of the different methods discussed.

A. H.

Applied X-rays. By GEORGE L. CLARK, Ph.D. Second Edition. [Pp. xiv + 470, with 239 figures.] (London: McGraw-Hill Publishing Co., 1932. Price 30*s.* net.)

THE trouble about science nowadays is that it continually goes on and goes on quickly, whatever else loiters; and were it not for the gallant efforts of writers of such books as the one under review and of journals such as the one in which this review appears, the rest of us would soon find ourselves —in a matter of half a dozen years or so—living in a kind of perpetual Dark Age. Even the title, "Applied X-rays," conveys a world of meaning, for there seems to be no end to the applications of X-rays in anything involving atoms and molecules. The present volume, which has been included in the International Series in Physics, is a second edition (the first was published in 1927), but actually Professor Clark has had to re-write practically the whole book and expand it to almost twice its original size It is now divided into two main parts, one dealing with the "General Physics and Applications of X-radiation" (including chapters on Radiography and the Physical, Chemical, and Biological Effects of X-rays), and the other with the "X-ray Analysis of the Ultimate Structure of Materials." In such wide fields, as the author himself points out, the treatment is suggestive rather than exhaustive, but much ground is covered and Professor Clark deserves well of us for reviewing the situation so admirably. X-rays constitute one of the most powerful and far-reaching of modern research tools, whether in academic or industrial science, and it is only through the aid of books like *Applied X-rays* that one can appreciate the enormous progress that has been made and the rich promise for the future.

W. T. ASTBURY.

The Technique of Ultra-Violet Radiology. By D. T. HARRIS, M.B., B.S., D.Sc., F.Inst.P. [Pp. viii + 166, with 109 plates and illustrations.] (London: Blackie & Son, Ltd., 1932. Price 6*s.* net.)

IN the preface to this volume the author states that it has been written primarily for those technicians and laboratory workers who have to handle ultra-violet generators. From this point of view the work is very well executed, containing, as it does, practical information on the various methods of generating ultra-violet radiation, on the measurement of this radiation and on the physiological uses to which the radiation can be put. The general reader, however, will not find the book easy reading unless he possesses a fairly considerable knowledge of physics, since the treatment is so concise as to render the book primarily a laboratory manual—as such, however, it should prove extraordinarily useful. The book is extremely well-produced and illustrated and can be recommended without reserve.

A. H.

Commission Internationale de l'Eclairage. Recueil des travaux et compte rendu des séances, 1931. [Pp. 694, with 60 diagrams and illustrations and 37 plates.] (Published under the direction of the National Physical Laboratory, Teddington, by the Cambridge University Press, 1932. Price 20*s.* net.)

THIS volume is the official account of the proceedings of the meeting of the International Commission on Illumination held at Cambridge in September 1931. It illustrates how rapidly the work and scope of the Commission is

extending. Some idea of its activities will be obtained from a perusal of pages 41–3, on which are tabulated the problems recommended for study in the immediate future.

The volume incorporates the decisions taken at the meeting in 1931 and also the reports of the various national illumination committees on specific problems in illumination. The reports are reproduced in French, English, or German, and in most cases summaries are given in all three languages.

The subjects discussed cover many aspects of illumination research and practice, including street lighting, daylight illumination with its applications to fenestration, illumination in connection with advertising design and architecture, coloured glasses for use as signals and for traffic control, glare phenomena, motor-car headlights, photometry and standards of candle power and of brightness, colorimetry and colour specification, the lighting of schools and factories, diffusing materials and the distribution of light, lighting education (in regard to which the present facilities are reviewed and suggestions are put forward for school and college courses in illumination), aerial navigation lighting (summarising developments in the lighting of airports and airways and in the lighting equipment of aeroplanes). There is also a report on ultra-violet illumination; this represents a new field of activity and is recommended for further study on account of its bearing on health.

It will be surprising if illuminating engineers, and indeed all persons and bodies whose activities bring them into contact with illumination problems, do not derive much useful information from a perusal of these pages, which emphasise once more the importance of international exchange of experience and the value of such bodies as the International Commission on Illumination.

The book is well printed and is bound in blue buckram. It is evident that the Cambridge University Press has spared no effort to produce a volume fully representative of its high traditions.

L. J. C.

CHEMISTRY

Water Purification Control. By E. S. Hopkins. [Pp. 131, with 35 figures.] (London: Baillière, Tindall & Cox, 1932. Price 10*s*. net.)

Mr. Hopkins, who is chemist to the Bureau of Water Supply, Baltimore, has produced this clear and readable booklet with the object of improving the efficiency of operation of American waterworks. The adjective American is used since out of nearly 100 references in the text only two are not of this origin, although this limitation does not make the book less interesting to English readers.

It is divided into seven chapters headed respectively: Coagulation, Sedimentation, Filtration, Disinfection, Taste and Odours, Corrective Treatment, and Plant Control Data The chapter on Sedimentation is largely devoted to showing the beneficial effects of cross baffling in sedimentation tanks and it is here perhaps that a short résumé of the theory of sedimentation might have been included to help waterworks operators to apply the results to their own particular case with a rational view-point. Conditions vary so much in different localities that one cannot always use the identical method as suggested but has to carry out modifications to suit local requirements.

The chapter on Tastes and Odours shows that phenols and similar com-

pounds present in water, owing to the uncontrolled emission of waste waters containing them from coke-oven and gas plants and creosoting works, are very difficult to deal with, since when chlorinated they produce chloro-phenol products, which have a stronger taste than the original chemicals. This is surely an inverted system, the onus should be on the producers of these wastes to avoid discharging them into water supplies and not on the public to combat them through its waterworks officials.

The subject of Corrective Treatment is one which evokes many ideas for the future of our water supplies. It is concerned with the measures necessary to control the acidity due to free carbon dioxide in the water and thus avoid corrosion of mains and customers' pipe lines. Our immediate predecessors achieved the standard of bacteriological purity which we now enjoy—a high standard for their day—but not the utmost improvement in our water supplies of which modern science is capable. The knowledge in our hands to-day is just beginning to be utilized to give us chemically controlled water, which will conform more to the varied dietetic and household needs in each different district. Does not every advertisement for household water-softening appliances carry the implied criticism that improvements in our water supply are an urgent necessity? This book gives much food for thought on the chemical engineering aspects of the subject and should be a stimulating impetus to those for whom it is written.

M. B. Donald.

Calculations of Qualitative Analysis. By Carl J. Engelder, Ph.D. [Pp. viii + 174.] (New York: John Wiley & Sons, Inc.; London: Chapman & Hall, Ltd., 1933. Price 12*s.* 6*d.* net.)

This book is a collection of examples dealing with the simple calculations of qualitative analysis and chemical equilibria, for which subjects the author believes that the theory is adequately treated in numerous other books, so that accordingly in this one there is but the briefest mention of the theoretical principles on which the calculations are founded.

So far as the examples are concerned they appear to be clearly stated, and to be of types that are commonly met with, but the insertion of some less conventional calculations would have made the book more interesting. To the teacher requiring a source of examples to set to a class this book would prove valuable, but to a student trying to learn the subject by himself it would probably prove turgid. The book is quite unsuitable for use except in conjunction with a good textbook of general chemistry.

The range of the book may be judged from the first example, an exercise in simple addition, and the last in which the electrode potentials of the half-cell reactions of the various forms of the element manganese are required.

O. H. W.-J.

Laboratory Methods of Organic Chemistry. By L. Gattermann. Completely revised by Heinrich Wieland, translated from the 22nd German Edition by W. McCartney. [Pp. xviii + 416, with 52 illustrations.] (London: Macmillan & Co., 1932. Price 17*s.* net.)

Nearly forty years ago Gattermann wrote what was then the best practical organic chemistry and, although there are now many more claimants to pre-eminence, this new edition of a classic, revised by so eminent a chemist as Prof. Wieland, assumes a leading position almost of right. All that was so

valuable in the older work has been retained, the introduction dealing with manipulative methods, the careful description of experiments and the discussion of the chemistry involved therein, but many new preparations have been added involving general reactions of more recent discovery.

The close association between the student's practical work and his theoretical reading brought about by this book is invaluable and, although the average student would find time for but a selection of the preparations, the perusal of the descriptions and explanations of the experiments he does not attempt will be of very considerable help to him in the understanding of elementary organic chemistry.

However good a work of this kind may be, anyone closely associated with the teaching of practical organic chemistry will feel that he can suggest improvements. The section on manipulation is a little old-fashioned and would be better for the inclusion of a few of the modern methods which are generally available in well-equipped laboratories. Insufficient attention is paid to the manipulation of small quantities, particularly in connection with the preparation of derivatives for identification, for example, acetyl, benzoyl, 3 : 5-dinitrobenzoyl derivatives, semicarbazones, substituted phenylhydrazones and *p*-nitrobenzyl ethers. Although dangers are very generally indicated, the use of concentrated sulphuric acid in desiccators to be evacuated is still advocated; unless the desiccator is small, collapses are by no means uncommon and the risk of acid splash serious. As regards individual preparations, the method involving the use of kieselguhr to increase the interface between benzene and sulphuric acid in the preparation of benzene sulphonic acid might have been substituted for the older experiment as it introduces a new principle, and Barnet's modification of the preparation of quinoline, using ferric sulphate in place of nitrobenzene as the oxidising agent, has advantages over Skraup's synthesis. These however are minor criticisms of what is a very excellent book.

O. L. B.

Organic Syntheses. Vol. XII. Edited by F. C. Whitmore. [Pp. 96.] (New York: John Wiley & Sons; London: Chapman & Hall, Ltd., 1932. Price 10*s.* 6*d.* net.)

This annual publication of practicable methods of preparing organic compounds required for research purposes is now so well known that further praise or description is unnecessary.

The present volume deals with the preparation of acetylbenzoin, arginine, benzyl phthalimide, *p*-chlorobenzaldehyde, desoxybenzoin, desyl chloride, dibenzalacetone, 1 : 2-dibromocyclohexane, 2 : 6-diiodo-*p*-nitroaniline, 2 : 4-dinitrobenzaldehyde, 4 : 5-diphenylglyoxalone, ethyl $\alpha\beta$-dibromo-β-phenylpropionate, ethyl-N-methylcarbamate, hippuric acid, iodothiophene, mercury di-β-naphthyl, methyl isopropylcarbinol, S-methyl isothiourea, β-naphthylmercuric chloride, nitrobarbituric acid, phenylpropiolic acid, phenylthienyl ketone, propionaldehyde, succinic anhydride, β-thiodiglycol, thiophene, thiosalicylic acid, *p*-tolualdehyde, uramil and diethyl zinc.

The methods recommended have been fully tested and the above list is so catholic that there can be few organic research chemists who are not interested in one or other of the compounds whose preparation in reasonable quantities is described.

O. L. B.

The Biochemistry of Muscle. By DOROTHY MOYLE NEEDHAM. Methuen's Monographs on Biological Subjects. [Pp. viii + 166.] (Methuen & Co., Ltd., 1932. Price 5s. net.)

MRS. NEEDHAM is to be congratulated on the bold and successful way in which she has attempted to give a survey of the wide and difficult field of muscle chemistry within the limits of a book of under 170 small pages. The extent of the survey may be gauged from the fact that the bibliography includes 300 references. These references have been carefully selected and there are few matters of importance of which there is not at least a brief account.

It is permissible to wonder, however, whether the subject is not too large and complex for profitable treatment in such a small compass. A book of twice the size would be at least three times as valuable. As it is the book may well prove to be too small for the specialist and too specialised for the general reader.

A. D. H

Spices and Condiments. By H. STANLEY REDGROVE, B.Sc., F I.C. [Pp. xviii + 361, with numerous plates and illustrations.] (London: Sir Isaac Pitman & Sons, Ltd, 1933. Price 15s. net.)

THAT the quest for spices was a powerful incentive to voyages for discovery or trade in the past is a fact too well known to merit discussion; previous to the discovery of antiseptics and disinfectants, such as we have to-day, the only materials known as food preservatives were nature's spices which, besides exerting their beneficent action, provided pleasing flavours and aromas to the foods to which they were added. In spite of the great importance of spices in everyday life there are but few books containing, in compact form, the main facts concerning these very important articles of commerce; it is to remedy this state of things that the author undertook the task of compiling the present volume. At the outset the difficulty of classification was encountered; the varied points of view of the botanist, the spice grower and the chemist have been compromised by adopting as a basis the part of the plant from which the spice is obtained. The book is accordingly divided into six sections, of which the first is an Introduction, while the remaining five are devoted to Rhizome and Root Spices, Bark, Flower, Fruit and Seed Spices respectively. The information imparted under this classification regarding each of the many spices and condiments described includes a botanical description, historical notes, what is known of the chemistry of the constituents and an account of the uses of the substances. The book is well illustrated, is remarkably free from misprints, and contains a great deal of information presented in a most interesting way. It can be strongly recommended to the notice of all who seek enlightenment on the uses and significance of spices.

P. H.

Hydrogen Ion Concentration and its Practical Applications. By FRANK L. LAMOTTE, WILLIAM R. KENNY and ALLEN B. REED. [Pp. viii + 262, with 15 figures.] (London: Baillière, Tindall & Cox, 1932. Price 20s. net.)

THE authors state that they have endeavoured to set forth the fundamental principles of hydrogen ion control in a manner that would prove helpful

to the operating chemist. No attempt has been made to present a discourse on the scientific aspects of hydrogen ion measurements, since this has already been provided by eminent authors. The book is therefore addressed to the practical technologist in search of a working knowledge of the hydrogen ion control; in view of the manifold applications of this question and the increasing recognition of its importance in almost every field of applied chemistry the appearance of such a book as this should be welcomed by a large army of workers who approach the subject from different view-points. The book is divided into two sections, A and B, of which the first is devoted to the mechanism of hydrogen ion determinations; it deals in simple terms with such subjects as buffer action, salt error, temperature effect, etc. In Section B the practical application of hydrogen ion determinations is described in relation to such varied subjects as Water Supply, Water Corrosion Problems, the Sugar Industry, Gelatine and Glue, Leather Manufacture, Textile Industry, Food Industry, etc. The biological applications, moreover, also receive attention, two chapters being devoted to Bacteriology, Pathology and Titration procedures and to Soils respectively. A feature of the latter chapter is that in addition to giving quite a good summary of the subject of soil acidity there is included a long list of plants with their soil preferences, compiled by Wherry, together with a short bibliography and selected references.

P. H.

Ninth Report of the Committee on Contact Catalysis, National Research Council. By J. N. PEARCE. Reprinted from the *Journal of Physical Chemistry*, vol. XXXVI, 1932. [Pp. 1969–2010.] (Price 50 cents)

THIS report abstracts a number of original papers, on the following and allied subjects: adsorption on charcoal, on catalytic powders, on crystal faces and edges, on metals; heat of adsorption; unimolecular films on aqueous solutions, soap films; hydrogenation, dehydrogenation; oxidation, formation of oxide films on metals; sundry additive reactions; decomposition. No papers published later than 1930 are reviewed. The material is not critically dealt with nor is much attempt made to correlate the different sections of the review. As a review of literature, it will be useful to those directly interested in contact catalysis or adsorption, though an interval of nearly two years between the date of publication of the report and of the last papers abstracted seems too long. Theoretical questions are only touched upon incidentally, in a manner which will probably be disappointing to both specialist and non-specialist readers.

N. K. A.

GEOLOGY

Summary of Progress of the Geological Survey of Great Britain and the Museum of Practical Geology for the year 1932. Part I. [Pp. iv + 98.] (H.M. Stationery Office, 1933. Price 2*s*. net.)

As in previous years, Part I of the *Summary of Progress* has been devoted to a brief statement of the actual progress of the various units of the Geological Survey. From this we see the enormous and varied field covered by the Survey. Not only is the pure geological work being carried out as formerly, but each year seems to add to the list of "contacts" between the pure

science of the Survey and the technical uses to which geology is being put, for instance, the preparation of soil texture maps, the study of building stones and geophysical work.

Much of the six-inch field mapping is a primary survey on that scale and even when a district is resurveyed (*e.g.* the coalfields) the amount of new information available here means that the new map is of vastly more practical value than the old one. This state of affairs is permanent, so that by the time the whole of Britain is surveyed or resurveyed on the six-inch scale, much of it will be in a state justifying a new resurvey.

Naturally a considerable portion of the time of the Staff has been taken up in preparing for the move to the new quarters in South Kensington. The report by the Director gives us some idea of what we may expect to find when the new building is in the occupation of its rightful owners. The old idea of an exhibit with every square inch packed with a specimen is being given up and in the new exhibits, maps, models, photographs as well as selected specimens with explanatory notes will fill the space. These should prove of great educational value and stimulate many to study the Science.

W. B. R. K.

Physics of the Earth—V. Oceanography. Bulletin of the National Research Council, No. 85 [Pp. v + 581, with numerous figures.] (Washington, 1932. Price $5)

This book is an excellent summary of our knowledge of Oceanography, viewing the latter as a branch of Geophysics. After a general introduction by Heck, Littlehales discusses the configuration of the oceanic basins, and Collet treats of deep-sea deposits. The physical and chemical properties of sea water are then dealt with by T G. Thompson and R. J. Robinson in two long chapters, the second of which includes a section, by Iver Igelsrud, on the formation of oceanic salt deposits.

Chapters VI to IX inclusive treat of the movements of sea water, waves being dealt with by Patton and Marmer, tides by Marmer alone, while G. F. McEwen outlines the basic principles underlying modern methods of dynamical oceanography, and oceanic circulation is surveyed by Schumacher. Ice in the sea is the subject of Chapter X, by Ed H. Smith. Next come two chapters on oceanographic instruments and methods by Soule and Parker.

The final section considers the relations of oceanography to other sciences; of these meteorology is discussed by C. F. Brooks, biology by A. G. Huntsman, while C. Schuchert deals with the periodicity of oceanic spreading, mountain making and palæogeography.

When provided with so much useful matter at so reasonable a price it may seem ungracious to point out omissions or defects, but *The Seas* by F. S. Russell and C. M. Yonge might be added to the popular introductory books listed. The division dealing with the physics and chemistry of sea-water is the most comprehensive survey published since Quinton's book of 1912, but the section on colour and transparency does not mention Forel's colour scale and omits all work since 1926.

On p. 385 one finds "large quantities of SO_2 are removed . . . this substance . . ." Since the medium is the sea, the statement is obviously inexact. On p. 429 the rapid rotting of silk plankton nets is mentioned, but not their preservation by copper oleate. On p. 464 Maury's (1860) map

of the Gulf Stream drift is given; it shows the position of the Sargasso Sea, incorrectly, as lying across the Canary Islands Stream and might with advantage be replaced by a more recent map, such as that given by G. Schott in 1912 in his fine work, *Geographie des Atlantischen Ozeans.* Chapter XVI makes no mention of Joly's theory of oceanic transgression as set forth in his *Surface-history of the Earth* (Oxford, 1925).

The work as a whole shows a certain amount of repetition, due to its composite nature. The arrangement of the indexes is a go-as-you-please affair, in six the items appear merely numbered in their order as in text, which wastes time when hunting up a reference. Six others are in alphabetical order, while four short chapters have none.

W. R. G. Atkins.

The Form and Properties of Crystals. By A. B. Dale, M.A. [Pp. vii + 186, with 122 illustrations.] (Cambridge: At the University Press, 1932. Price 6*s.* net.)

In this small volume, an attempt is made to give the student whose main interests are petrological an introduction to crystallography which shall suffice for his immediate needs, more especially in relation to microscopical studies. Unfortunately, however, it is difficult to see what possible help could be derived from the use of this book: the purely formal theorems such as those on projections can be found in abundance elsewhere, and when crystal optics are discussed the mistakes and obscurities are numerous enough to render the treatment of more than doubtful value. A symmetrical bi-axial conoscopic figure is depicted deprived of one of its brushes: an ellipsoid apparently depends for its existence upon the axes to which it happens to be referred; and so on.

These things apart, the book is not a pleasure to read: "higgledy-piggledy" seems a needlessly unlovely epithet to use twice in a brief outline of one of the most exact (not to mention one of the most beautiful) of the physical sciences.

F. I. G. Rawlins.

BOTANY

Root Nodule Bacteria and Leguminous Plants. By Edwin Broun Fred, Ira Lawrence Baldwin and Elizabeth McCoy. University of Wisconsin Studies in Science, No. 5. [Pp. xxii + 343, illustrated with numerous plates.] (Madison, 1932. Price $3.)

The beneficial effect of leguminous crops upon the soil has been recognised by many generations of farmers; thus the Roman writer Varro in the year 37 B.C. recommended planting of legumes in a light soil, not so much for their own crops as for the good they do to subsequent crops; similarly Pliny in A.D. 79 claims for lupines that they enriched the soil of a vineyard as well as any manure. In spite of the antiquity of this empirically gained knowledge the reason for the beneficial action of leguminous plants was not understood until Hellriegel and Wilfarth in 1886 explained the significance of the root nodules in enabling these plants to obtain supplies of nitrogen from the atmosphere by the help of symbiotic bacteria. Although these two workers had thus laid bare the essential facts of the process, much has remained to be done in studying the various aspects of the problem, such as the isolation and life cycle of the organisms and the recognition of distinct

species associated with different groups of leguminous plants. To the investigation of these problems workers from all over the world have contributed and a vast amount of literature on the subject has been produced. The present monograph is an attempt, and a very successful one, to correlate the results of all these workers. The text is divided into thirteen chapters; some of the subjects dealt with are as follows: The isolation and study of the Root Nodule Bacteria, their morphology and life cycle, their cultural and biochemical characteristics, factors which influence their growth and longevity; other chapters are devoted to species relationships, factors that influence nodule production, economic importance of leguminous crops, and natural and artificial inoculation. A section also deals with nodules of non-leguminous plants, some of which are root and others leaf forms. The book is provided with 46 full-page plates, some of which are reproductions of plates from historical herbals illustrating plants with root nodules attached. Those interested in the subject of root nodule bacteria will find in this book an indispensable source of reference on all aspects of the subject.

P. H.

Plant Ecology. By William Leach, D.Sc. [Pp. viii + 104, with 6 figures.] (London: Methuen & Co., Ltd., 1933. Price 3*s*. 6*d*. net.)

This little book forms a useful elementary introduction to the subject of Plant Ecology. Two-thirds of the text are concerned with the factors governing plant distribution, followed by some hints as to practical work and a very brief description of some of the chief types of British vegetation. The work should prove useful to those requiring a simple introduction to the subject, but it is unfortunate that the author has not furnished literature references for further study. The literature cited is a short and curious selection of extensive and intensive studies.

E. J. S.

An Introduction to Tropical Soils. By Dr. P. Vageler. Translated by Dr. H. Greene. [Pp. xvi + 240, with 12 plates and 13 figures.] (London: Macmillan & Co., Ltd., 1933. Price 15*s*. net.)

The paucity of literature on tropical soils and the striking features which they present in comparison with those of temperate regions, renders a work of this character peculiarly welcome. The author emphasises the fact that under tropical conditions the standards by which a soil is judged are entirely altered. Instances are cited where the real acidity and calcium deficiency of certain soils, as judged by experience in temperate regions, would be inimical to plant life, yet actually under tropical conditions these soils support satisfactory crops. So too do some soils that under European conditions would be inadequately aerated.

The high temperatures bring about a rate of chemical change that may be from two to four times as rapid as in a temperate clime, and, since there is no interruption through the advent of a cold season, weathering is continuous and probably proceeds about ten times faster than in temperate countries. Furthermore, the high rainfall not only involves rapid removal of soluble material, but it is estimated that from thirty to thirty-five pounds of pure nitric acid are added every year per acre in tropical regions through rainfall. This must clearly intensify the rate of oxidation in no small degree.

The high rainfall has other important effects, noticeably in relation to transport of material, and the author rightly emphasises the effect of the concentration of this high precipitation in heavy downpours, which results in greatly augmenting the proportion which "runs off" the surface. This the author regards as an important factor in determining the local soil climate. Stress is laid on the great importance of wind action, and on the marked temperature changes, which latter are sufficiently great to replace in the magnitude of their effects the action of frost and ice in northern latitudes.

It is these differences, as compared with temperate conditions, which render this work of interest to the student of temperate soils. The author's experience of twenty years' personal study of tropical conditions gives the text a first-hand quality that is reflected in the vivid picture which is presented, and which should ensure its value to the planter for whom it is primarily written. Nevertheless, though in no sense either encyclopædic or a textbook the work can be confidently recommended to the pedologist and ecologist as a valuable portrayal of tropical conditions.

E. J. S.

ZOOLOGY

Theoretische Biologie. Bd. I: Allgemeine Theorie, Physikochemie, Aufbau und Entwicklung des Organismus. By LUDWIG V. BERTALANFFY. [Pp xii + 349] (Berlin: Borntraeger, 1932. Price 18 RM., paper covers; 20 RM bound.)

THE work of Dr. Ludwig von Bertalanffy on biological method is not sufficiently well known in this country. He is one of a small band of people who are paving the way to a new conception of the organism, a new orientation of biological thought. Ritter in America, J. S. Haldane and Woodger in England, may be mentioned as pioneers along this road. They all propound in one form or another an "organismic" view of the living thing, which is offered as a way of escape from the mechanism-vitalism dilemma.

In the introductory section of this book, which is the first volume of a general review of biological data from the organismic point of view, Bertalanffy discusses the shortcomings of the old-fashioned mechanistic conception, and the inadmissibility of the vitalistic view, which he regards as unscientific in so far as it implies the postulation of a regulating agency, whether psychical or metaphysical. He points out that while the mechanistic method is applicable to the single parts and processes of the organism, considered in abstraction from the whole, it cannot deal adequately with that active and intimate correlation of all the parts and all the processes to form a whole, which constitutes the essential characteristic of the living thing. It is impossible by summing up or adding together these separated parts and processes to reconstitute the living whole. The living thing is a *system* of organisation, and the main task of the biologist must be to discover the laws of such systems—laws to which the activities of the parts are subordinated. These laws cannot at present be formulated in physico-chemical terms, and perhaps never will be; they must be regarded as biological laws existing in their own right. As an example, take the law of "biological maintenance," which might be formulated in some such form as this—"the organic system tends to self-conservation." This is a fundamental law or characteristic of the organism, governing many of its subordinate activities.

The biologist must take account of the "hierarchical" arrangement of organic structure and function, and seek to discover first the laws applying to organic activity at its highest level, working downwards to the lower levels; he should not attempt to build up the whole-activity by adding together the abstract elements distinguished by analysis at the lowest or chemical level, which is the method adopted by the mechanist.

This is a position with which—as I have held it for many years—I naturally have every sympathy. It seems to me to open up the best line of advance in the theory and practice of biology. I should be inclined to go farther than Dr. Bertalanffy and include as an integral part of biology the study of behaviour. Bertalanffy eliminates psychology from the field of biology on the ground that it introduces the "private facts" of direct experience. I do not think this objection is altogether well founded. The facts of behaviour are certainly objective and "public," and to account for them it is by no means necessary to make hypotheses about their inner quality. Much of behaviour shows the objective characteristics of conative activity; we can treat it as such without troubling ourselves about psychological concepts like "soul," "consciousness," or "conation," or enquiring as to the nature of such activity as experienced by the individual exhibiting it. So too we can, I think, demonstrate the existence of perceptive activity by considering the objective facts of behaviour, but we do not need to explain this as due to "perception." We can in practice avoid the dualism of matter and mind, and that introduction of psychical agencies to which Bertalanffy quite rightly objects.

Behaviour can of course be studied also from the strictly "behaviouristic" or physiological point of view, and this kind of study Bertalanffy would include as a legitimate part of biology. But behaviour shows, perhaps more clearly than any other organic activity, that wholeness and directedness in time which excludes the possibility of dealing with it adequately on an analytical-summative basis; it is *par excellence* the activity which lends itself easily to organismic treatment, and it seems a pity to relegate it to a separate science, as Bertalanffy advocates. I do not see how it is possible to form a complete and comprehensive view of organic activities without taking behaviour into account. It is, in animals at least, one of the most potent means of self-maintenance, and it plays a great part in reproduction also. In instinctive activities particularly we see the very close relation which exists between behaviour and morphogenesis. In my view then a satisfactory organismic theory of the organism must include some elements of psychobiology.

The introductory section of Bertalanffy's book, in which these questions of method are discussed, takes up approximately one third of it, and is followed by chapters on the physics and chemistry of protoplasm and the structure and physiology of the cell. The last section deals in a very interesting way with the excessively difficult problems of development. These were treated more fully in Bertalanffy's previous book *Kritische Theorie der Formbildung* (1928), which has recently been translated into English by Dr. Woodger, with modifications and additions, including some sections from the methodological part of the present book.

No one who is interested in the theory and method of biology can afford to neglect these two books of Bertalanffy.

E. S. R.

Invertebrate Zoology. By Robert W. Hegner, Ph.D. [Pp. xiii + 570, with 403 illustrations.] (New York: The Macmillan Company, 1933. Price 20*s*. net.)

A great deal of information for the student is contained in compact form in this volume. It is for the most part well up to date, and is set forth under leaded headings, with plenty of clearly drawn illustrations, chiefly from line drawings. Each of the sections devoted to the principal groups opens with a description in some detail of one or more types, with passages upon matters of general zoology which they may illustrate, and this is followed by the brief description of a number of examples, arranged in a classification. The chapters on the several phyla have some rather scanty introductory remarks, and at the end a general section, in which various phenomena are surveyed for the whole phylum. Both the introductions and the general sections, however, are unsatisfactory in that they fail to give a really illuminating picture of the essential peculiarities of the phyla, and though the book contains much interesting detail, it does in this respect—in a certain lack of grasp and inspiration—leave a good deal to be desired.

Naturally enough, there are minor points which seem open to criticism. The bald definition of the Protozoa as "unicellular animals" would be better justified if it were certain either that the uninucleate protozoon is truly comparable to a cell of a metazoon or that the Protozoa are animals. The statement that "the characteristic organ [of the Mollusca] is a ventral muscular foot" rather surprisingly ignores the mantle, shell, and ctenidia; and the radula and fundamental lay-out of the nervous system surely deserve mention in a summary of the general features of molluscs. The treatment of the Crustacea is inadequate. If the Peracarida are mentioned as a group, their remarkable common feature should be stated, and the absence of any allusion to the very peculiar organisation of creatures so common as the crabs is a serious omission. The morphology of *Limulus* is deserving of more description than it receives. The mention without explanation of the "lantern" of a holothurian (p. 535) is misleading.

The book, however, will undoubtedly be useful to the classes for which it is intended.

L. A. B.

Fundamentals of Biology. By Arthur W. Haupt, Ph.D. 2nd Edition. [Pp. x + 403, with 277 figures.] (London: McGraw-Hill Publishing Co., 1932. Price 18*s*. net.)

In this volume the author has provided a general introduction to Biology, on the whole as illustrated by a series of types of both animals and plants, but he has covered a wide field in his choice of material. The contents include the cell, the various groups of plants and of animals, and a series of more general chapters dealing with Metabolism and irritability, Heredity, the Application of the principles of heredity, Adaptation, Saprophitism, Parasitism, Evolution including the evolution of Man. The book is intended "as a presentation of the basic principles common to all living things, with emphasis on those aspects of biology which seem to be of greatest value in contributing to a liberal education . . ." It appears to fulfil this intention well. It is obviously intended for a first-year university or college course and covers a wider field and goes into less detail than is customary in this country. This is no disadvantage when the course is not a preliminary

to a technical course like medicine. This is the second edition of the book and there have been alterations in both text and illustrations that have added to its usefulness. It is very well printed, indexed and illustrated, and will, we think, form a useful book on general biology.

C. H. O'D.

The Mammal-like Reptiles of South Africa and the Origin of Mammals. By Robert Broom, D.Sc., F.R.S. [Pp. xvi + 376, with 111 figures.] (London: H. F. and G. Witherby, 1932. Price 25s. net.)

The problem of the origin of the mammals is one that possesses considerable interest seeing that we ourselves represent the end product of one line of evolution in that group. Just as we regard the Fayoum district of northern Africa as the classical terrain in a consideration of the origin of the Proboscidea, so the Karroo of South Africa with its wonderful range of fossil reptiles is to be looked to for the origin of the Mammalia. Among the names of those who have delved in this rich field that of Robert Broom holds an eminent place and he has attained world recognition as an authority on this assemblage of forms.

The book, therefore, suggests interest from many aspects nor will its reader be disappointed. There are four main parts to the book: a description of the Karroo system of fossiliferous beds, a critical survey of the numerous remains that have been collected therefrom, a discussion of the origin of the mammals, and brief personal notes on some of the fossil hunters of the Karroo. Naturally with the wealth of material available the second of these is by far the most extensive. The last, while brief, adds a very human touch to the work.

There are a few criticisms of the book to be made from the point of view of the general reader. Firstly, it would have been of assistance to have given in tabular form the relationships of the different beds of the Karroo system. Secondly, perusal would have been rendered easier by the provision of a diagram of the relationships of the various groups discussed The constant use of the terms Dinocephalians, Anomodonts, Dicynodonts, Gorgonopsians, Bauriomorphs, Therapsids, Anapsids, etc, while comprehensible to the expert familiar with the classification and terminology employed, is somewhat bewildering to the general zoologist without some such aid. Thirdly, the value of the many illustrations would have been enhanced if indication of the scale of magnification or reduction were provided. In Fig. 6 it does state that all the drawings are to the same scale, but does not say what scale. Sometimes measurements are given in the text, but not commonly. Lastly, although agreeing with much that the author has to say respecting illustrations of this type of material, we think that, while most of the drawings are adequate, some might have been better executed. This is demonstrated in the first figure, where C is very sketchy.

Apart from these criticisms which apply to the presentation and not to the subject matter, the book deserves every commendation The large number of forms described, hitherto almost all to be found only in widely scattered papers, give the general zoologist access to a mass of information which he would never have time to search out for himself. Moreover, the excellent bibliography makes access to the original descriptions quite easy. In this alone a noteworthy service has been rendered. But the descriptions

are the more valuable since they are critically drawn up in the light of the author's vast knowledge and experience. The discussions are also useful and enlightening and the general summary presents the author's views on the origin of the mammals from the reptiles, which he considers to be derived from the Ictidosauria, a sub-order of the Therapsida It is a pity, but no fault of the author's, that as the two most valuable specimens of this little known and important order are awaiting description they have no scientific names but are referred to as Ictidosaurian A and B.

C. H. O'D.

Deep-Sea Angler-Fishes Ceratioidea. By C. TATE REGAN, D.Sc., F.R.S., Director of the British Museum (Natural History), and ETHELWYNN TREWAVAS, B.Sc. The Carlsberg Foundation's Oceanographical Expedition round the World, 1928–30, under the Leadership of Professor Johannes Schmidt, Ph.D., D.Sc. Report No. 2. [Pp. 1–113, with 10 plates and 172 figures in the text] (Published by the Carlsberg Foundation: Copenhagen, C A. Reitzels Forlag; London, Milford, Oxford University Press, 1932. Price 15*s*. net.)

IN 1926 Dr. Tate Regan published an account of the Ceratioid Fishes collected by the *Dana* (1920–2) in the North Atlantic, the Caribbean Sea and the Gulf of Panama. Sixty species were then recognised, several more have been added since and the magnificent new material from the same vessel in her voyage round the world fully demonstrates the astonishing variety of these deep-sea anglers, bringing the total to 158 species and necessitating new systematic revision.

The Pediculati or Angler-fishes are provided with a line or lure formed from the first ray of the dorsal fin. In the Ceratioidea this lure is luminous, the anglers belonging to the group usually inhabiting the warmer parts and living normally in the middle depths of the oceans, from about 500 to 2,000 metres below the surface. The pelvic fins are absent and the body is of a uniform generally blackish colouration.

One of the chief points of interest is the presence of dwarf parasitic males which cling to the females and become intimately connected. These males show many peculiar features and the continuity of the blood system of male and female, indicated but not certainly demonstrated, in *Ceratias*, is now proved in *Edriolychnus*, showing that the males are truly parasitic, and there can be little doubt that they do not become mature until they have attached themselves to the females. Although parasitic males are found in four families, in others it is found that they are free-swimming, becoming sexually mature at a much smaller size than the females and differing from them widely in form and habit.

Beautiful results have been obtained for studying the osteology of these fishes by staining with alizarin and clearing, the cranial characters being systematically important and also the number of the pectoral radials and the presence or absence of pelvic bones. The lateral line organs may also be used to a certain extent in classification.

Special attention should be drawn to the excellent figures both in the text and plates. Colonel Tenison gives a personality to these fishes with their strangely variable lures and fins and grotesque shapes which is astonishingly life-like.

M. V. L.

A Report on the Fisheries of Uganda. Investigated by the Cambridge Expedition to the East African Lakes, 1930–1, with 3 Appendices, 5 maps and 21 other illustrations. By E. B. WORTHINGTON, M.A., Ph.D., Balfour Student at Cambridge University. [Pp. 88.] (Published on behalf of the Government of Uganda Protectorate by the Crown Agents for the Colonies, 1932. Price 7*s.* 6*d.* net.)

THIS report is based on detailed investigations of the Uganda Lakes, carried on by the Cambridge Expedition from May to September 1931 by arrangement with the Uganda Government following immediately similar work in Kenya Colony. It forms a companion volume to Mr. M Graham's report on the Lake Victoria Fisheries and the present writer's report on the Fisheries of Lakes Albert and Kioga, the three volumes containing valuable data and information as to the future development of the Uganda Fisheries.

The larger lakes, Lake Edward and Lake George, offer excellent opportunities for salt fish industry. The most important fishes are *Protopterus æthiopicus*, *Clarias lazera* and *Tilapia nilotica*, *Protopterus* and *Clarias* being predacious and *Tilapia* living on plankton. It is important that when *Tilapia* is fished the predacious fishes which prey upon it should be fished also and this must be taken into account in all fishery control.

Smaller lakes were also investigated. Here the much discussed question of the advisability of introducing fish from other waters is approached. In Lake Bunyoni, which was formed in quite recent times by volcanic activity, there are no indigenous fishes at all, but the introduced *Clarias carsonii* is doing well. Various suggestions are made for further introductions and rules as to size limit for *Clarius*, the females being much smaller than the males. *Tilapia nigra* and the Black Bass are mentioned as likely to do well.

The notes on the distribution of crocodiles are very interesting, for they are absent in Lake George and Lake Edward. This is important for the fisheries as they do much damage. It is shown that in former times they did exist and the author suggests that desiccation, known to have taken place after the first of the pluvial periods, must have dried up Lake Edward completely. Subsequently it again became a lake and its existing fauna came from Lake Victoria. From that time to the present day the crocodiles and larger fishes were prevented from ascending the Semliki River from Lake Albert by the Semliki Falls. In some of the other lakes the crocodiles appear to have died out quite recently, possibly owing to secondary desiccation.

M. V. L.

Physiology of Farm Animals. By F. H. A. MARSHALL and E. T. HALNAN. [Pp. xiv + 366, with 118 illustrations.] (Cambridge and London: Cambridge University Press, 1932. Price 15*s.* net.)

"THE PHYSIOLOGY OF FARM ANIMALS," Part I, by F. H. A. Marshall, appeared in 1920 and is now out of print. It dealt with general principles and in some detail with Reproduction. A companion volume on Nutrition by the late Prof. T. B. Wood was intended but never completed. The present volume is a revisal of the original Part I with which is incorporated chapters on Nutrition and certain other aspects of physiology which were either omitted from the first edition or received but brief mention. The second author has been mainly responsible for the preparation of these new sections.

In general the work of incórporation has been accomplished with success, but in some sections the difficulties of joint authorship are apparent; for example, at the end of the book there are consecutive chapters on Reproduction, Heredity and Sex, Response of the Body to Injury and Disease, Growth and then a number of chapters on Metabolism and Nutrition. This sequence appears to lack continuity and the chapters on Metabolism and Nutrition are too widely separated from the sections on digestion, absorption and excretion near the beginning of the book. The book is specially intended for students of Agriculture and due prominence is given to the important subjects of Nutrition and Reproduction. It is however more than a class textbook and should be valuable to post-graduate students and all those who desire to know something of the physiology of the domesticated animals. To the veterinary student it should be of special use. Up to the present the veterinary has been largely a general practitioner with knowledge of pathology and clinical medicine but without the grounding in animal husbandry which might enable him to act as livestock adviser to his farmer clients. This book should go a long way towards making good this deficiency. The fundamental principles of physiology are illustrated as far as possible with data derived from farm animals. Those aspects of physiology which are of interest mainly to the specialist, such as the physiology of muscle, nerve, circulation and respiration, are treated briefly but adequately. A short chapter on the Nervous System is sufficient to illustrate the principles of nervous co-ordination, but a more generous treatment of conditioned reflexes and the part they play in behaviour might have been included. As one would expect from the authorship the chapters on Reproduction are outstanding. The most recent research is included in a concise yet ample account and the student is not overburdened by discussion of the many conflicting and tentative hypotheses which at present tend to complicate the endocrinological aspects of the subject. The chapters on Metabolism and Nutrition cover all the more important aspects and include most of the recent research on animal nutrition. The chapter on the vitamins is concise and lucid. The book is very well illustrated and a number of new figures have been specially drawn for the book by the junior author.

ARTHUR WALTON.

Insects, Man's Chief Competitors. By W. P. FLINT and C. L. METCALF. [Pp. viii + 134, with 12 figures.] (Baltimore: The Williams and Wilkins Co., 1932. Agents, Baillière, Tindall & Cox, London. Price 5*s*. 6*d*. net.)

THESE two American authors need no further introduction beyond the mention of their two recent books, *Destructive and Useful Insects* and *Fundamentals of Insect Life*. Both men are exceptionally well qualified to write a popular book on insects.

It is during the last 100 years that entomology has grown from almost nothing into a science involving the material prosperity and health of mankind. In spite of this, the general public does not yet appreciate the extent to which insects permeate man's activities. Flint and Metcalf set out to remedy this defect and to provide, especially for boys and girls, more information about insects, their ravages and the means employed in fighting them.

In Chapter I they give a vivid pen picture of the facts that make insects the most destructive and dangerous group of animals on earth: their damage

to growing crops, their modes of feeding, their transport of plant, animal, and human diseases and their inroads into stored products. In Chapter II the methods of insect control are observed during an air trip over the United States. In the third the structure of insects is explained simply and in the next chapter there is an imaginary review of the insect army with explanations of the characteristics of the different battalions or insect orders as they pass by.

Then finally a series of insect biographies are given as simple short stories. The subjects of these life-history studies are well chosen and comprise the Grape Phylloxera, Fleas and the Black Death, Ox Warbles, the Hessian fly, the Periodical Cicada, the Colorado Potato beetle and the Cotton Boll weevil. In each case the means used in combating these pests are carefully explained.

The whole book is written in an attractive manner. It would have perhaps been slightly more pleasant to read if the authors had been less prone to produce startling figures and facts which may sound too exaggerated to the lay adult mind, yet nevertheless can be well authenticated. The illustrations are of unequal standard, but the format of the book is excellent. To achieve the author's aim thoroughly the book should have been a little lower in price. We heartily recommend the book as one of the best really popular books on entomology.

H. F. B.

MEDICINE

Sound Conduction and Hearing. By A. Zünd-Burguet. Translated by Macleod Yearsley, F.R.C.S. [Pp. 139.] (John Bale, Sons & Danielsson, Ltd., 1932. Price 8*s*. net.)

The theory of hearing has received a good deal of attention from both physiologists and physicists of late. Dr. Zünd-Burguet's book deals with one aspect of this, and that such a small one that one wonders that a book of this size can be written on it. The problem discussed is, in fact, whether sound reaches the inner ear via the ear-drum and ossicles (" bone conduction ") or whether it travels via the air of the Eustachian tube. The question is presented in the form of a critical survey of the literature of this very specialised branch of medico-physics since the time of Aristotle up to the beginning of the present century.

It is very difficult to review such a book. For one thing, one cannot tell when the author is quoting other authorities, and when he is giving his own opinions. Further, his critical judgment should have been exercised to a greater extent, and he should have tried to clear away the inconsistencies and pedantic obscurities which encumber the statements of many of the savants whom he cites as authorities. One does not expect otologists to be equipped with the jargon of physics, but one rather grieves for biological science on reading statements such as the following, attributed to Bonnier: "It is necessary to distinguish two forms of disturbance, according as the elasticity of the disturbed medium is considered molecule by molecule, or as a matter of the total mass suspended and free to oscillate in totality to a certain extent." Instances of obscure statements such as this could be picked out from most of the pages of the book. It is possible of course that Dr. Zünd-Burguet was not well served by his translator. Indeed, it is evident in certain places that the translator has not understood the author's

meaning, and has translated word for word, for one can read the French into the translation, so to speak.

A chapter is devoted to hearing proper, and the theory of Helmholtz comes in for criticism. One is aware that certain physiologists find this theory a stumbling-block, but surely it is not fair to say (p. 115) "The numerous objections which this theory has occasioned have led all modern authors to reject it." One is not encouraged to regard a book on audition as authoritative in which the work of physiologists who were also physicists is either dismissed (e.g. Helmholtz) or not mentioned (e.g. Wilkinson, Banister).

Considered purely as an "historical study" the book will however be found of great value, for it furnishes the only generally available source book in the history of bone conduction, but it is a pity the author has not made his notes up to date by including recent work.

E. G. R.

Bacteriophage in the Treatment and Prevention of Cholera. By J. Morison, C.I.E., M.B., D.P.H. [Pp. 32, with 14 plates, 27 figures, and 4 graphs.] (London: H. K. Lewis & Co., 1932. Price 4*s*. net.)

For this essay, Lieut.-Colonel J. Morison, I.M.S., director of the King Edward VII Pasteur Institute and Medical Research Institute, Shillong, Assam, was awarded the Parkin Prize by the Royal College of Physicians, Edinburgh. It presents the author's views on the cholera problem in India, his methods of preparing cholera bacteriophage and the inconclusive results of field experiments on the therapeutic value of the phage. The author's evidence for assigning the spread of cholera to infected water is intelligently presented, but it conflicts with the generally accepted conclusions as given in Greig's article in the *M.R.C. System of Bacteriology*, Vol. IV, 1929, which Colonel Morison does not appear to have studied.

Tom Hare.

English Medicine and the Cambridge School. By W. Langdon Brown, M.A., M.D., F.R.C.P. [Pp. 52.] (Cambridge University Press, 1932. Price 2*s*. net.)

"I am inclined to . . . claim that the term, the Humanities, is an apt description of the medical sciences." This striking and characteristic utterance by Prof. W. Langdon Brown occurs towards the end of the lecture delivered on the occasion of his inauguration as Regius Professor of Physic at the University of Cambridge. The chair was founded by Henry VIII in 1540 and although for about three centuries medicine does not appear to have flourished in the Cambridge climate, yet in the last few decades the tree planted so long ago has suddenly sprung into vigorous life and has already borne rich and remarkable fruit. Amongst other distinguished names which we meet in this lecture, Paget, Gaskell, Langley, Rivers and Gowland Hopkins are a not unrepresentative selection. The variety of their interests gives some indication of the wide conception which the author has of his subject. The lecture is full of interesting detail and is broadly philosophic in its treatment. In the classical world the development of ethics largely held up the growth of its embryonic science; in the modern world science threatens to have its revenge. Can science and ethics be

reconciled? Prof. Langdon Brown puts this question and although he does not answer it directly, he suggests that the sciences of medicine may point the direction in which a reconciliation may be effected.

W. O. K.

Studies on the Physiology of the Eye. Still Reaction, Sleep, Dreams, Hibernation, Repression, Coma and Allied Conditions. By J. GRANDSON BYRNE, M.D. [Pp. xii + 416, with 48 illustrations.] (London: H. K. Lewis & Co., Ltd., 1933. Price 40s. net.)

THE innervation of the eye is a subject of much interest to the physiologist and the clinician. In this work many new facts have been elicited. The major part of the book is taken up with descriptions of experiments. Each chapter contains a full account of the technique employed; the findings of other investigators are then discussed and compared with those of the author, followed by a summary. Although this method has advantages, it tends to cause repetition of facts given earlier in the book But this is a small point and is more than compensated by the careful description of detail which subsequent workers will find useful.

The mechanisms producing palpebral, pupillary and lens movements with those of the eyeball as a whole, are dealt with; and in their development three stages are postulated, the chemical or lowest, next the chemico-neural, and finally reflex activity. These are related to the basic reactions in approach, standstill and avoidance. The Sharpey-Schafer phenomenon is ascribed to pseudo- and true paradoxical dilatation on the side of the first sympathetic section. Hibernation and death-feigning are traced through the animal kingdom and are found to be identical with the sleep of the higher types. In discussing the pupillary reactions to light it was found that, on sudden illumination, the pupil first dilates. Wherever possible the clinical application of experimental findings are pointed out. Thus, in discussing paradoxical dilatation of the pupil, the importance of excluding an afferent nerve lesion, before assuming injury to the cervical sympathetic, is stressed. The book is well illustrated and contains a full bibliography.

W. A. G.

PHILOSOPHY AND HISTORY OF SCIENCE

The Anatomy of Modern Science, An Introduction to the Scientific Philosophy of To-day. By BERNHARD BAVINK. Translated by H. STAFFORD HATFIELD. [Pp. 700, with 87 figures and 12 plates.] (London: G. Bell & Sons, Ltd., 1932. Price 21s. net.)

THE publishers have done their best to arouse interest in Dr. Bavink's book. "With a knowledge which has aroused the admiration of men of science for its extent and accuracy, and with a clarity of style and thought that makes this book an open and attractive one to all serious readers, Dr. Bavink herein presents a broad survey of the anatomy of modern science. He brings into the balance the great discoveries of recent times in all fields, and draws positive conclusions as to the bearing of scientific results upon the fundamental problems of human destiny, and spiritual beliefs." These and even more luring assertions printed on the dust-cover naturally filled me with great expectations. But my reading of the book has not fulfilled the expectations aroused in me. A good deal of praise is indeed due to the author for the way in which he has carried out his gigantic task; but with the best will in the

world I cannot subscribe to the publishers' claim that he "has performed his task brilliantly." The book does indeed give a satisfactory survey of the broad results of recent scientific research. But a similar and much fuller account is to be found in the *Outlines of Modern Knowledge* for the small sum of five shillings. And as for the "positive conclusions" which the author draws about "the fundamental problems of human destiny," I must say reluctantly that the book shows little evidence of a deep knowledge of philosophy, and contains nothing that has not been said already, and said much better in various English books. However, there is some advantage in reading such a single-handed attempt to take one's orientation in the world on a scientific basis, and readers may well profit from the study of Dr. Bavink's book provided they are sufficiently critical to discriminate carefully between the scientific and the merely homiletical portions of it.

Although the bulk of Dr. Bavink's volume is taken up with summary accounts of scientific results these accounts are only a means to an end, for, as the title of the book makes it clear, the author is mainly concerned with the philosophic questions which they raise. Of the philosophic questions thus discussed those which receive most attention are the epistemological ones, that is the problems concerning the nature and validity of human knowledge. Dr. Bavink describes himself as a follower of critical realism. The main tenet of this brand of epistemology is that our so-called knowledge when it is obtained on critical or scientific lines is not a subjective illusion, or merely a matter of conventional, economic or pragmatic formulæ, but a real apprehension of objective facts which exist independently of our apprehension of them. The author repeats quite satisfactorily the criticisms advanced by numerous realists against rival theories of knowledge, and one follows him very sympathetically. Suddenly, however, one's faith in his grasp of the theory is thoroughly shaken when, almost without any warning, certainly without any reason worth mention, he identifies his objective realities with objective *ideas*. His realism is thus of the Scholastic type, and merely Platonic idealism. Knowledge consequently is now described as concerned with objective "truths," as distinguished, say, from material and other facts. This needs some justification. For just as error is a misapprehension of facts, so truth is simply the apprehension of facts as they really are, more or less. Or does Dr. Bavink regard "error" too as something objective? If so, then those who are in error apprehend something objective, just like those who apprehend truth. But, since the author does not even mention the problem of error, inseparable though it is from the problem of knowledge or truth, the matter need not be pursued further.

Having proved to his own satisfaction the objectivity of truth, Dr. Bavink next attempts to establish the objectivity of such value-concepts as those of beauty, goodness and holiness. The best that he has to say on these topics is not nearly as good as what has been said, for instance, by such a populariser as the late Lord Balfour; and it is not even clear whether he really knows what the problem of values is, quite apart from its correct solution. However, many people may find it all edifying, and it can do them no harm.

Dr. Bavink betrays his unfamiliarity with contemporary philosophy rather badly when he attributes to the Americans the credit for the purely British conception of "emergence," which he uses frequently. He also has very little knowledge of some of the greatest philosophers of the past among whose ideas he gropes rather helplessly. Moreover, his toying with Nordic nonsense, while at the same time claiming racial kinship between the Ger-

manic and Hindu peoples, shakes one's confidence in the reliability of the "balance" to which his publishers allude. And there is even just a suspicion of propaganda in his assurance that the Germans would have progressed morally if they had won the war. Needless to say, he does not refer to the Treaty of Brest-Litovsk as evidence of the moral progress of a victorious Germany.

A few words must be added about the translation. Obviously the translator had a formidable task before him, and he must be credited with a considerable measure of success—I have seen much worse translations. But it would be idle to pretend that it is a good translation. Apart from its frequent clumsiness, it is sometimes quite unintelligible without first guessing what the German original may have been, and occasionally it is quite wrong. I append just a few examples, with corrections in brackets: p. 66, categorical (categorial); p. 73, prius and posterius (antecedent and consequent); pp. 89, 416, etc., conscientialism (mentalism or pan-psychism); p. 231, resolutive and compositive (analytic and synthetic); p. 387, if once . . . always (if ever); p. 576, Jesaiah (Isaiah). Also a couple of misprints (not the only ones): p. 202, casual (causal); p. 404, most (must).

A. Wolf.

Modern Alchemy. By William Albert Noyes and W. Albert Noyes, Jun. [Pp. x + 208, with 17 figures.] (London: Baillière, Tindall & Cox, 1932. Price 17*s*. 6*d*. net.)

Search for the Philosopher's Stone and an Elixir of Life initiated indirectly much scientific enquiry, but one scarcely realises the width of scientific knowledge thus acquired. This book by Noyes and Noyes reveals, to anyone interested in physics, chemistry, metallurgy or medicine, how far these sciences are interconnected, and how varied are the investigations that may be classified as "Modern Alchemy." The authors are not content with merely collecting under one cover results of interconnected sciences; in each they indicate the frontier separating the known from the unknown, and this particularly impresses upon one the increasing dependence of metallurgy and medicine on further advances in the older sciences.

The book opens with paragraphs tracing briefly the development of physical, geological and medical sciences, evolution and history, and this enables the authors to indicate the general method of science and its application to particular subjects. The reader is then introduced to what might be termed pure modern alchemy, namely, the structure of the atom, transmutation of elements, valency, molecular spectra, and photochemistry. The history of each is given from early conceptions of matter up to the most recent results of modern theory and experiment; thus one finds mentioned the vector atom and its relation to quantum mechanics, artificial disintegration of elements, Heitler-London theory of valence, and Slater and Pauling's quantum mechanical orientation of the carbon valencies.

Thereafter one learns of applied modern alchemy. A fascinating account of the production of special alloys and high-speed steels indicates the methods of metallurgy. The concluding chapter turns to the "Elixir of Life"; "science of healing" suggests better the contents of this account of chemistry in the prevention and cure of disease, in aseptic surgery, and in elucidating the nature of hormones and vitamins; finally one is shown the difficulties

of explaining how the body converts chemical into mechanical energy whilst working at an almost constant temperature.

The treatment of such a variety of subjects in a short volume necessitates a very brief survey of each, and the consequent jumps from one to another makes a first reading appear disjointed. On the other hand only a concise exposition can bring the interconnection of the many subjects clearly before the reader; this has been the aim of the authors, and it gives the book value and interest either for the specialist in any one of the sciences mentioned, or for anyone interested in the varied and most recent advances of modern alchemy.

The book is excellently produced, and a bibliography at the end of each chapter should prove helpful to those seeking greater detail in any subject.

A. B. D. Cassie.

MISCELLANEOUS

The Subject Index to Periodicals, 1931. [Pp ix + 534.] (London: The Library Association, 1932. Price £3 10*s*.)

The Library Association is to be congratulated upon its production of the volume of the Subject Index covering periodicals issued during 1931 only eight months after its previous volume. It is evident that the Association has gathered together a very energetic and capable team of indexers under the general editorship of Mr. T. Rowland Powel, who is responsible for the present volume. The book is as well produced as its predecessors and contains well over 25,000 entries arranged under the subject headings adopted by the Library of Congress, U.S.A. To scientists its value would obviously be greater if the number of foreign technical journals indexed were increased, but it must not be forgotten that the Library Association deals deliberately only with those periodicals which are not covered by the various specialised abstracting journals. How far the Association is prepared to go in the effort to keep pace with the constantly growing rate of production of scientific literature remains to be seen. It might perhaps be worth considering whether the addition of a number of periodicals at present omitted from the list of those indexed would lead to greater usefulness; the Italian journals included in the present volume number only two, while the Scandinavian countries, Spain, and Japan are not represented at all.

J. A. W.

The Royal Society of Canada. Fifty Years' Retrospect. Anniversary Volume 1882–1932. [Pp. xxiv + 179.]

Inaugurated in 1882, the Royal Society of Canada celebrated last year its fiftieth Anniversary and this volume records its activities over that period. The early days were difficult ones, but once these were overcome, much important work developed, and now the Society's existence is a necessary part of the educational life of the Dominion.

The book before us contains a series of papers surveying the progress in Canada of the various subjects covered by the five sections of the Society, and constitutes a unique record of achievements in the intellectual and scientific life of Canada for half a century. In addition to the natural sciences, the Society embraces History, Literature, Archæology, Statistics, Political and Economic Science. Sir Robert Falconer, in his Presidential

Address, gives a summary of the Society's history, and makes many important suggestions for a wider scope in its already many and varied activities. An important and useful work, since it provides a record of what has been achieved by the Society as a whole and by its individual members.

H. W. R.

Intelligence and Intelligence Tests. By REX KNIGHT, M.A. [Pp. x + 98, with 2 figures.] (London: Methuen & Co., Ltd. Price 2*s*. 6*d*. net.)

THIS is an excellent little book. It is not only intended for the student of psychology and the professional teacher, but also for that increasing body of the public who take an intelligent interest in psychology; and for all three classes of reader it can be thoroughly recommended. After a brief introduction in which Mr Knight refers to the curious disparagement of intelligence in favour of qualities of character by which an individual is esteemed in this country, the author begins with an exceedingly simple and clear exposition of the "two-factor" theory of intelligence. Statistical methods are not easy to make plain to those who have not studied them in detail; yet it is safe to say that the chapter dealing with the deduction of a constant cognitive "factor" in the mental endowment of human beings, together with variable "factors" which severally enter into the performance of different mental operations, will be understood without difficulty by anyone who reads it. An examination of the nature of this constant factor of intelligence (varying, it is to be noted, from one person to another) follows. This chapter embodies a criticism of the definitions of intelligence advanced by several psychologists, in favour of a slightly modified form of the well-known teaching of Spearman. After disposing of different physiological accounts of intelligence that have been put forward, Mr. Knight deals with the usual intelligence tests, of which he gives samples; and he goes on to relate a number of established facts in respect of intelligence which will prove of great interest to the non-psychological reader. The last chapter is occupied with the uses of the tests in actual practice—the diagnosis of mental deficiency, the grading of pupils in schools, the treatment of "difficult" children, and vocational guidance and selection. "Intelligence and Intelligence Tests" deserves a wide and appreciative public.

F. A.

BOOKS RECEIVED

(Publishers are requested to notify prices)

The Fourier Integral and certain of its applications. By Norbert Wiener, Professor of Mathematics at the Massachusetts Institute of Technology. Cambridge: at the University Press. (Pp. xii + 201.) Price 12*s*. 6*d*. net.

Functions of a Complex Variable. By Thomas M. Macrobert, M.A., D.Sc., Professor of Mathematics in the University of Glasgow. Second Edition. London: Macmillan & Co., Ltd., 1933. (Pp. xvi + 347, with 83 figures.) Price 14*s*. net.

Contributions to the Calculus of Variations 1931–1932. Theses submitted to the Department of Mathematics of the University of Chicago. U.S.A.: University of Chicago Press, 1933. Great Britain & Ireland: Cambridge University Press. (Pp. 523.) Price 16*s*. 6*d*. net.

Handbook of Mathematical Tables and Formulas. Compiled by Richard Stevens Burington, Ph.D., Department of Mathematics, Case School of Applied Science, Cleveland. Sandusky, Ohio: Handbook Publishers, Inc., 1933. (Pp. vi + 251, with 57 figures.) Price $2.00.

Network Synthesis. Synthesis of a Finite Four-Terminal Network from Its Prescribed Driving-Point Functions and Transfer Function. By Charles M:Son Gewertz, E.E., Sc.M., Sc.D. London: Baillière, Tindall & Cox, 1933. (Pp. vi + 258, with 57 figures.) Price 23*s*. net.

Rayleigh's Principle and its Applications to Engineering. The Theory and Practice of the Energy Method for the Approximate Determination of Critical Loads and Speeds. By G. Temple, Ph.D., D.Sc., Professor of Mathematics in the University of London, King's College, and W. G. Bickley, D.Sc., Assistant Professor of Mathematics, City and Guilds (Engineering) College, Reader in Mathematics in the University of London. London: Oxford University Press, 1933. (Pp. x + 156, with 22 figures.) Price 14*s*. net.

Numerology. By E. T. Bell, Ph.D., Professor of Mathematics in the California Institute of Technology. Baltimore: The Williams & Wilkins Company. London: Baillière, Tindall & Cox, 1933. (Pp. viii + 188, with 4 figures.) Price 11*s*. 6*d*. net.

Elementary Calculus. Vol. I. By C. V. Durell, M.A., Senior Mathematical Master, Winchester College, and A. Robson, M.A., Senior Mathematical Master, Marlborough College. London: G. Bell & Sons, Ltd., 1933. (Pp. viii + 240, with 107 figures.) Price 4*s*. 6*d*., without appendix 3*s*. 6*d*.

Planetary Co-ordinates for the years 1800–1940 referred to the equinox of 1950·0. Prepared by H.M. Nautical Almanac Office. London: H.M. Stationery Office, 1933. (Pp. xviii + 156.) Price 12*s*. 6*d*. net.

Makers of Astronomy. By Hector Macpherson, M.A., Ph.D., F.R.S.E., F.R.A.S. Oxford: At the Clarendon Press. London: Humphrey Milford, 1933. (Pp. x + 244, with 9 illustrations.) Price 7*s*. 6*d*. net.

Spectroscopy in Science and Industry. An Introductory Manual describing its applications to industrial and other practical problems. By S. Judd Lewis, D.Sc. (London), D.Sc. (Tübingen), F.I.C., Ph.C. London and Glasgow: Blackie & Son, Ltd., 1933. (Pp. viii + 94, with 41 figures.) Price 3*s*. 6*d*. net.

The Universe of Light. By Sir William Bragg, O.M., K.B.E., D.Sc., F.R.S., Honorary Fellow of Trinity College, Cambridge; Fullerian Professor in the Royal Institution of Great Britain. London: G. Bell & Sons, Ltd., 1933. (Pp. xii + 283, with 26 Plates.) Price 12*s*. 6*d*. net.

Commission Internationale de l'Eclairage. En succession à la commission internationale de Photométrie. Huitième session, Cambridge—Septembre 1931. Recueil des travaux et compte rendu des séances. Publié sous la direction du Bureau Central de la Commission, The National Physical Laboratory, Teddington, Angleterre. Cambridge: at the University Press, 1932. (Pp. 694, with illustrations.) Price 20*s*. net.

The Ostwald Colour Album. A complete collection of colour standards for use in colour specification and the study of colour harmony. Arranged by J. Scott Taylor, M.A. London: Winsor & Newton, Ltd., 1933. (12 plates.) Price 21*s*. net.

Infra-Red Photography. By S. O. Rawling, D.Sc., F.I.C., F.R.P.S. London and Glasgow: Blackie & Son, Ltd., 1933. (Pp. x + 58, with 12 plates and 17 text figures.) Price 3*s*. 6*d*. net.

Experimental Atomic Physics. By G. P. Harnwell, Ph.D., Assistant Professor of Physics, Princeton University, and J. J. Livingood, Ph.D., Research Associate, The University of California. New York and London: McGraw-Hill Book Company, Inc., 1933. (Pp. xiv + 472, with 175 figures.) Price 30*s*. net.

Collision Processes in Gases. By F. L. Arnot, B.Sc., Ph.D.(Camb.), F.R.S.E., Lecturer in Natural Philosophy in the University of St. Andrews. London: Methuen & Co., Ltd., 1933. (Pp. viii + 104, with 37 diagrams.) Price 2*s*. 6*d*. net.

The Development of Physical Thought. A Survey Course of Modern Physics. By Leonard B. Loeb, Professor of Physics, University of California, and Arthur S. Adams, Professor of Mechanics, Colorado School of Mines. New York: John Wiley & Sons, Inc. London: Chapman & Hall, Ltd., 1933. (Pp. xvi + 648, with 120 figures.) Price 23*s*. net.

Theory of Thermionic Vacuum Tubes. Fundamentals—Amplifiers—Detectors. By E. Leon Chaffee, Ph.D., Professor of Physics, Harvard University. New York and London: McGraw-Hill Book Company, Inc., 1933. (Pp. xxiv + 652, with 360 figures and 6 plates.) Price 36*s*. net.

Traveling Waves on Transmission Systems. By L. V. Bewley, Power Transformer Engineering Department, General Electric Company, Pittsfield, Mass. New York: John Wiley & Sons, Inc. London: Chapman & Hall, Ltd., 1933. (Pp. viii + 334, with 133 figures.) Price 28*s*. net.

High-Frequency Measurements. By August Hund, Fellow of the American Physical Society, Institute of Radio Engineers, American Association for the Advancement of Science. New York and London: McGraw-Hill Book Company, Inc., 1933. (Pp. x + 491, with 373 figures.) Price 30*s*. net.

Wireless Over Thirty Years. By R. N. Vyvyan. London: George Routledge & Sons, Ltd., 1933. (Pp. xiv + 256, with 16 plates and 12 diagrams.) Price 8*s*. 6*d*. net.

Practical Acoustics for the Constructor. By C. W. Glover, A.M.Inst.C.E., M.I.Struct.E., L.R.I.B.A., Member Acoustical Society, Lecturer on Acoustics at the Regent Street Polytechnic, London. London: Chapman & Hall, Ltd., 1933. (Pp. xii + 468, with 193 figures and illustrated appendix.) Price 25*s*. net.

Heat. By James M. Cork, Ph.D., Associate Professor of Physics, University of Michigan. New York: John Wiley & Sons, Inc. London: Chapman & Hall, Ltd., 1933. (Pp. xii + 279, with 115 figures.) Price 18*s*. 6*d*. net.

Gas Analysis by Measurement of Thermal Conductivity. By H. A. Daynes, D.Sc., F.Inst.P. Cambridge: at the University Press, 1933. (Pp. viii + 357, with 76 figures.) Price 16*s*. net.

Outline of a Physics Course for Schools. By E. H. Nelthorpe, B.Sc., A.R.C.Sc., D.I.C., Senior Physics Master, Erith County School. London: John Murray, 1933. (Pp. 192, with 104 figures.) Price 2*s*. 6*d*.

A Text Book on Heat. By A. W. Barton, M.A., Ph.D., sometime Senior Scholar of Trinity College, Cambridge, Assistant Master at Repton School. London: Longmans, Green & Co., 1933. (Pp. xiv + 378, with 110 figures.) Price 7*s*. 6*d*.

General Science. An Introductory Course. By H. G. Mitchell, M.A., B.Sc., sometime Sizar of Trinity College, Cambridge; Science Master at County High School for Boys, Altrincham. London: John Murray, 1933. (Pp. viii + 325, with 195 figures.) Price 3*s*. 6*d*.

The Kinetics of Chemical Change in Gaseous Systems. By C. N. Hinshelwood, M.A., F.R.S., Fellow of Trinity College, Oxford, Messel Research Fellow of the Royal Society, Lecturer in Chemical Dynamics, University of Oxford. Third Edition. Oxford: at the Clarendon Press. London: Humphrey Milford, 1933. (Pp. viii + 392, with 17 figures.) Price 15*s*. net.

The Cotton Effect and Related Phenomena. By Stotherd Mitchell, D.Sc. (Glas.), Lecturer in Physical Chemistry, University of Glasgow. London: G. Bell & Sons, Ltd., 1933. (Pp. viii + 92, with 34 figures.) Price 7*s*. 6*d*. net.

Handbuch der Anorganischen Chemie. Abegg, Auerbach, Koppel. IV. Band, 3. Abteilung: Die Elemente der 8. Gruppe des periodischen Systems. Zweiter Teil: Eisen und seine Verbindungen. Lieferung A 2 (Mai 1933). Herausgegeben von Dr. I. Koppel, a.o. Professor an der Universität zu Berlin. Leipzig: Verlag von S. Hirzel, 1933. (Pp. xii + 222, with 96 figures.) Price RM. 21—, paper covers.

Industrial Chemistry. By William Thornton Read, Dean of the School of Chemistry, Rutgers University. New York: John Wiley & Sons, Inc. London: Chapman & Hall, Ltd., 1933. (Pp. viii + 576, with 130 figures.) Price 31*s*. net.

Principles of Fruit Preservation. Jam making, canning and drying. By J. N. Morris, M.A., University of Cambridge and Department of Scientific Research, Low Temperature Research Station. Being Vol. VI of a series of monographs on applied chemistry. Under the Editorship of E. Howard Tripp, Ph.D. London: Chapman & Hall, Ltd., 1933. (Pp. xiv + 239, with 36 figures.) Price 15*s*. net.

The Vitamins in Health and Disease. By Barnett Sure, Ph.D., Professor of Agricultural Chemistry, University of Arkansas. London: Baillière, Tindall & Cox, 1933. (Pp. xiv + 206.) Price 11*s*. 6*d*. net.

Practical Physiological Chemistry. By Sydney W. Cole, M.A., Trinity College, Cambridge, University Lecturer in Medical Chemistry, Cambridge. 9th Edition. Cambridge: W. Heffer & Sons, Ltd., 1933. (Pp. xii + 420, with 71 figures.) Price 12*s*. 6*d*. net.

Physical Chemistry for Students of Biology and Medicine. By David Ingersoll Hitchcock, Ph.D., Associate Professor of Physiology in the Yale University School of Medicine. London: Baillière, Tindall & Cox, 1932. (Pp. xii + 182, with 26 figures.) Price 15*s*. 6*d*. net.

A Textbook of Elementary Qualitative Analysis. By Carl J. Engelder, Ph.D., Professor of Analytical Chemistry, University of Pittsburgh. 2nd Edition. New York: John Wiley & Sons, Inc. London: Chapman & Hall, Ltd., 1933. (Pp. viii + 243, with 20 tables.) Price 13*s*. 6*d*. net.

Qualitative Analysis. By H. S. Moodey, M.A., Senior Science Master at Hampton Grammar School. London: William Heinemann, Ltd., 1933. (Pp. x + 182, with 15 figures.) Price 5*s*.

Organic Chemistry. By F. Sherwood Taylor, Ph.D., M.A., B.Sc., Assistant Master at Repton School. London: William Heinemann, Ltd., 1933. (Pp. xii + 587, with 56 figures.) Price 10*s*. 6*d*.

A Beginner's Chemistry. By Clifford M. Jones, M.Sc., Senior Chemistry Master, Wheelwright Grammar School, Dewsbury. London: John Murray, 1933. (Pp. viii + 135, with 44 figures and frontispiece.) Price 2*s*.

A Textbook of Geology. Part II—Historical Geology. By Charles Schuchert, Professor Emeritus of Paleontology in Yale University, and Carl O. Dunbar, Professor of Paleontology and Stratigraphy in Yale University. Third Edition, largely rewritten. New York: John Wiley & Sons, Inc. London: Chapman & Hall, Ltd., 1933. (Pp. viii + 551, with 332 figures.) Price 25*s*. net.

Igneous Rocks and the Depths of the Earth. Containing some revised chapters of "Igneous Rocks and Their Origin" (1914). By Reginald Aldworth Daly, Professor of Geology, Harvard University. New York and London: McGraw-Hill Book Company, Inc., 1933. (Pp. xvi + 598, with 190 figures and 3 plates.) Price 30*s*. net.

Historical Geology. By Raymond C. Moore, Ph.D. (University of Chicago), Professor of Geology, University of Kansas, and State Geologist of Kansas; Geologist, United States Geological Survey. New York and London: McGraw-Hill Book Company, Inc., 1933. (Pp. xiv + 674, with 413 figures and 2 other illustrations.) Price 24*s*. net.

Summary of Progress of the Geological Survey of Great Britain and the Museum of Practical Geology for the Year 1932. Part I. With Report of the Geological Survey Board and Report of the Director. London: H.M. Stationery Office, 1933. (Pp. iv + 98.) Price 2*s*. net.

An Introduction to the Study of Map Projections. By J. A. Steers, M.A., Fellow and Dean of St. Catharine's College, University Lecturer in Geography. With a Foreword by F. Debenham, M.A., O.B.E., Fellow of Gonville and Caius College, and Professor of Geography in the University of Cambridge. Third Edition, revised and enlarged. London: University of London Press, Ltd., 1933. (Pp. xxiv + 227, with 91 figures.) Price 8*s*. 6*d*. net.

The Making of Geography. By R. E. Dickinson and O. J. R. Howarth. Oxford: at the Clarendon Press. London: Humphrey Milford, 1933. (Pp. viii + 264, with 30 figures and 5 plates.) Price 8*s*. 6*d*. net.

The Poetry of Geology. By Kenneth Knight Hallowes, M.A. (Cantab.), F.G.S., A.R.S.M., A.Inst.M.M., F.R.M.S., F.Inst.P., Member Royal Society of Literature, Professional Geologist (1905–1926), H.M. Geological Survey of India. London: Thomas Murby & Co., 1933. (Pp. xii + 62.) Price 6*s*. net.

This Land of Ours. A simple explanation of the basis of scenery. By William Platt, Lecturer for the Selborne Society, the London County Council, the British Empire Naturalists' Association, etc. London: George Allen & Unwin, Ltd., 1933. (Pp. 104, with frontispiece, 8 plates and 14 illustrations in the text.) Price 2*s*.

Plants Useful to Man. By Wilfred William Robbins of the University of California and Francis Ramaley of the University of Colorado. Philadelphia: P. Blakiston's Son & Co., Inc., 1933. (Pp. viii + 428, with 241 figures.) Price \$3.00 post paid.

Phytopathological and Botanical Research Methods. By Thomas Elsworth Rawlins, Assistant Professor of Plant Pathology, University of California, Berkeley, California. New York: John Wiley & Sons, Inc. London: Chapman & Hall, Ltd., 1933. (Pp. x + 156, with 3 figures.) Price 15*s*. 6*d*. net.

An Introduction to Biology. By Elbert C. Cole, Ph.D., Professor of Biology, Williams College. New York: John Wiley & Sons, Inc. London: Chapman & Hall, Ltd., 1933. (Pp. xiv + 518, with 291 figures.) Price 11*s*. net.

Textbook of General Zoology. By Winterton C. Curtis, Professor of Zoology, University of Missouri, and Mary J. Guthrie, Associate Professor of Zoology, University of Missouri. With the collaboration of Katharine R. Jeffers, Instructor in Zoology, University of Missouri. 2nd Edition, rewritten and reset. New York: John Wiley & Sons, Inc. London: Chapman & Hall, Ltd., 1933. (Pp. xvi + 588, with 438 figures.) Price 23*s*. net.

An Introduction to Zoology. Through the study of the vertebrates with special reference to the rat and man. By Zeno Payne Metcalf, D.Sc., Professor of Zoology, North Carolina State College. London: Baillière, Tindall & Cox, 1932. (Pp. xx + 426, with 184 figures.) Price 20*s*. net.

An Introduction to the Vertebrates. By Leverett Allen Adams, Assistant Professor of Zoology, University of Illinois. New York: John Wiley & Sons, Inc. London: Chapman & Hall, Ltd., 1933. (Pp. vi + 414, with 290 figures.) Price 21*s*. 6*d*. net.

Invertebrate Zoology. By Robert W. Hegner, Ph.D., Professor of Protozoology in the School of Hygiene and Public Health of the Johns Hopkins University. New York: The Macmillan Company, 1933. (Pp. xiv + 570, with 403 figures.) Price 20*s*. net.

Economic Mammalogy. By Junius Henderson, Curator of University of Colorado Museum, and Elberta L. Craig, Museum Assistant. London: Baillière, Tindall & Cox, 1932. (Pp. x + 398.) Price 26*s*. net.

The Fresh-Water Algæ of the United States. By Gilbert M. Smith, Professor of Botany, Stanford University. New York and London: McGraw-Hill Book Company, Inc., 1933. (Pp. xii + 716, with 449 figures.) Price 36*s*. net.

Fishes. Their Journeys and Migrations. By Louis Roule. Professor at the National Museum of Natural History in Paris, Foreign Member of the Zoological Society of London. Translated from the French by Conrad Elphinstone. London: George Routledge & Sons, Ltd., 1933. (Pp. x + 270, with 64 figures.) Price 12*s*. 6*d*. net.

Fighting the Insects. The Story of an Entomologist. By L. O. Howard. New York: The Macmillan Company, 1933. (Pp. xviii + 333.) Price 12*s*. 6*d*. net.

Mimicry. By G. D. Hale Carpenter, M.B.E., D.M., Hope Professor of Zoology, Oxford. With a section on its genetic aspect by E. B. Ford, M.A., B.Sc., Lecturer in Genetics and University Demonstrator in the Department of Zoology and Comparative Anatomy, Oxford. London: Methuen & Co., Ltd., 1933. (Pp. x + 134, with 2 plates.) Price 3*s*. 6*d*. net.

Biology in Everyday Life. By John R. Baker and J. B. S. Haldane. London: George Allen & Unwin, Ltd., 1933. (Pp. 124.) Price 3*s*. 6*d*. net.

Junior Biology. By J. W. Stork, M.A., Biology Master, Charterhouse, Godalming, and L. P. W. Renouf, B.A., Dip. Agric., Professor of Zoology, University College, Cork, Director of the Cork University Biological Station. London: John Murray, 1933. (Pp. xii + 220, with 87 figures and frontispiece.) Price 2*s*. 6*d*.

Therapeutic Uses of Infra-Red Rays. By W. Annandale Troup, M.C., M.B., Ch.B. (St. And.). With Foreword by Sir William Willcox, K.C.I.E., C.B., C.M.G., M.D., F.R.C.P. 2nd Edition. London: The Actinic Press, Ltd., 1933. (Pp. xiv + 92, with 18 plates and 2 diagrams.) Price 6*s*. 6*d*. net.

Studies on the Physiology of the Eye. Still Reaction, Sleep, Dreams, Hibernation, Repression, Hypnosis, Narcosis, Coma, and Allied Conditions. By J. Grandson Byrne. London: H. K. Lewis & Co., Ltd., 1933. (Pp. xii + 428, with 48 figures.) Price 40*s*. net.

Food and the Principles of Dietetics. By Robert Hutchison, M.D., F.R.C.P., Physician to the London Hospital and to the Hospital for Sick Children, Great Ormond Street, and V. H. Mottram, M.A., Professor of Physiology at King's College of Household and Social Science, University of London. 7th Edition. London: Edward Arnold & Co., 1933. (Pp. xvi + 630, with 3 plates and 33 figures.) Price 21*s*. net.

Inherited Abnormalities of the Skin and its Appendages. By E. A. Cockayne, D.M., F.R.C.P., Physician to the Middlesex Hospital, Physician to Out-Patients, Hospital for Sick Children, Great Ormond Street. London: Oxford University Press, 1933. (Pp. x + 394.) Price 32*s*. net.

Stoke Park Monographs on Mental Deficiency and Other Problems of the Human Brain and Mind. No. I. The Burden Memorial Volume. Edited on behalf of the Medical and Consultant Staff of Stoke Park Colony, Stapleton, Bristol, by Richard J. A. Berry, M.D., F.R.C.S., F.R.S.E., Director of Medical Services. London: Macmillan & Co., Ltd., 1933. (Pp. xx + 249, with 91 illustrations.) Price 10*s*. 6*d*. net.

Leadership in Medicine. By Lord Moynihan. Walker Trust Lectures on Leadership No. IV, delivered before the University of St. Andrews, 16th February 1933. London: Oxford University Press, 1933. (Pp. 48.) Price 2*s*. 6*d*. net.

The Lamarck Manuscripts at Harvard. Edited by William Morton Wheeler and Thomas Barbour. Cambridge, Massachusetts: Harvard University Press. London: Humphrey Milford, 1933. (Pp. xxxii + 202, with 4 illustrations.) Price 12*s*. 6*d*. net.

The Herschel Chronicle. The Life-Story of William Herschel and His Sister Caroline Herschel. Edited by his Granddaughter Constance A. Lubbock. Cambridge: at the University Press, 1933. (Pp. xii + 388, with 9 illustrations.) Price 21*s*. net.

Science and Pseudo-Science. The Necessity for an Appeal Board for Science. By F. W. Edridge-Green, C.B.E., M.D., F.R.C.S., Special Examiner and Adviser to the Board of Trade on Colour Vision and Eyesight. London: John Bale, Sons & Danielsson, Ltd., 1933. (Pp. iv + 104.) Price 2*s*. 6*d*. net.

The Inventor and His World. By H. Stafford Hatfield, Ph.D. (London). London: Kegan Paul, Trench, Trubner & Co., Ltd., 1933. (Pp. vi + 269.) Price 6*s*. net.

Psychology and the Choice of a Career. By F. M. Earle, M.Ed., D.Sc., Principal of Kirkcaldy High School; formerly Head of the Vocational Department of the National Institute of Industrial Psychology; and sometime Professor of Education in the Rhodes University College, Grahamstown, South Africa. London: Methuen & Co., Ltd., 1933. (Pp. viii + 104, with 2 figures.) Price 2*s*. 6*d*. net.

Intelligence and Intelligence Tests. By Rex Knight, M.A., Anderson Lecturer in Comparative Psychology in the University of Aberdeen. London: Methuen & Co., Ltd., 1933. (Pp. x + 98, with 2 figures.) Price 2*s*. 6*d*. net.

Health and Education through Self-Mastery. By Anthony M. Ludovici. With a Foreword by Alfred Cox, O.B.E., M.A., LL.D., M.B. London: Watts & Co. (Pp. xvi + 125.) Price 3*s*. 6*d*. net.

Causality. A Law of Nature or a Maxim of the Naturalist? Lecture delivered at the Royal York Hotel, Toronto, on May 14th, 1932, much enlarged, by Ludwik Silberstein, Ph.D., formerly Lecturer in Mathematical Physics at the University of Rome. London: Macmillan & Co., Ltd., 1933. (Pp. viii + 159, with 1 figure.) Price 4*s*. 6*d*. net.

The Outlook of Science. Modern Materialism. By R. L. Worrall, M.B., Ch.M. London: John Bale, Sons & Danielsson, Ltd., 1933. (Pp. vi + 203.) Price 8*s*. 6*d*. net.

The Horse and the Sword. By Harold Peake and Herbert John Fleure. The Corridors of Time, VIII. Oxford: at the Clarendon Press. London: Humphrey Milford, 1933. (Pp. viii + 152, with 62 figures.) Price 5*s*. net.

Sacraments of Simple Folk. By R. R. Marett, Rector of Exeter College, Oxford, Fellow of the British Academy. Oxford: at the Clarendon Press. London: Humphrey Milford, 1933. (Pp viii + 230.) Price 10*s*. net.

SCIENCE PROGRESS

EPIDEMIOLOGY AS A BRANCH OF EXPERIMENTAL BIOLOGY

By PROFESSOR M. GREENWOOD, D.Sc., F.R.S.

EPIDEMIOLOGY has been defined as the study of disease regarded as a mass phenomenon ; a study the unit of observation of which is not a sick *individual* but a *group*. Disease is a biological response to particular stimuli and when we are primarily interested in the reactions to such stimuli of the individual, we are studying disease from the point of view of the physician ; when the individual is resolved into—to use an obsolescent terminology—body and soul and reactions studied from those two aspects, we have the view-points of the physiological and psychological physicians. When the analysis of " body " is carried further, it is thought of as systems of cells, the standpoint of the pathologist is reached. Passing in the opposite direction, synthesising the individuals into groups, we reach the epidemiological point of view. Undoubtedly the *ideal* epidemiologist should possess that knowledge of the individual peculiarities of sickness as manifested in and varying from man to man, which the good physician has ; the grasp of more intimate detail, which characterises the pathologist ; and that art of marshalling and summarising group characters into averages which belongs to the trained statistician. But here, as in all branches of scientific study, he who waits until his equipment for study is complete at all points will wait for ever. The epidemiologist who is not an experienced physician must accept his basic data, at least to some extent, on trust. He is provided, let us say, with a record of cases of Typhoid Fever said to have occurred in a community. Even if the events are recent, he will not be competent by examination of the patients to verify the alleged facts. On the other hand, a physician having that competence, may be unable to marshal the sifted data, to characterise the group phenomena. Men who could not have taken a platoon into action have written better military

history than professional soldiers. There have been excellent epidemiologists who would have been indifferent medical practitioners and many good physicians have written bad epidemiology. The first scientific epidemiologist, Hippocrates, was also a great practical physician and left for the use, or mis-use, of his successors, two inductive models. In one, he gave a scheme of note-taking, the object being to correlate the phases of herd sickness in a particular place with changes in the environment; in the other, he sought to correlate variations of herd sickness from place to place with racial, geographical and general environmental changes.

Hippocrates' most famous and influential successor, Galen, instead of urging his pupils to apply the inductive method on a wider scale, systematised such theoretical principles as were to be found in the writings of his predecessor into a deductive canon which seemed for more than 1,600 years to provide a complete description and explanation of epidemiological happenings. No real progress was effected, not because men were less intelligent than we are, not because they had less respect for logical reasoning (they had much more), but because they supposed that unsolved problems had really been solved Owing to the difficulty of assembling and collating objective data, they were unable to convince themselves that the formal solutions of the problems provided by Galen were *only* formal solutions. A biologist or a psychologist perusing the works of modern professional and amateur economic experts, may possibly have some sympathy with the difficulties of mediæval epidemiologists.

After the Renaissance, there was a partial return to the inductive method of Hippocrates; one of the prophets of this movement, the English physician Sydenham, actually attempted to do in London what Hippocrates had tried to do on the Isle of Thasos, *viz.* to write the history of herd sickness uninfluenced by theoretical presuppositions. In the opinion of some this attempt was successful; most readers have, however, felt that Sydenham's record is not sufficiently precise to allow a modern reader to test the conclusions which Sydenham drew, or supposed that he drew, from the observations. Sydenham, like his Greek predecessors, was seeking a general theory of epidemiology; for him, the ætiological differentiation of particular illnesses, although much more distinct than for Galen and Hippocrates, was far less distinct than for us and those of his successors, who, in the judgment of our age, achieved epidemiological success by using a method very unlike that of either Sydenham or Hippocrates. In the first place, a contemporary of Sydenham, John Graunt, although not a physician, drew attention to the

statistical method as a means of studying epidemiology and reached many important results in spite of the defects in available data. Largely owing to the impetus given by Graunt, statistical records of disease kept in civilised states gradually improved. Before the end of the eighteenth century, data of mortality tabulated by cause were sufficiently numerous and familiar to be used both by physicians and philanthropists as indices of herd sickness fit to be compared with statistics of factors which might be expected to affect group well-being.

In the next place, biologically minded pathologists like John Hunter prepared the ground for the experimental work of the nineteenth century which enabled all men to accept the biological doctrine of *contagium vivum* which was enunciated in 1546 by Girolamo Fracastori but did not greatly influence epidemiological opinion down to the middle of the eighteenth century.

The combined effect of these discoveries was that in the last century descriptive epidemiology has been transformed. If one compares a modern epidemiological study, for instance a competent official report on an outbreak of Typhoid Fever, with the writings of Sydenham or Huxham, its intellectual atmosphere is wholly different. Sydenham and Huxham are describing, or trying to describe, everything that happened. The modern writer takes the happenings separately. Even in general reviews of herd sickness, such as provided in the annual text volume of the Reports of the Registrar-General, general epidemiology fills a much smaller space than special epidemiology.

The practical advantage of this change of method has been great. To take a single instance, our knowledge of the herd ætiology of those "continued fevers" which we now call the typhoid group, was far more extended between 1833 and 1933 than in the whole 2,300 years which would bring us back from 1833 to Hippocrates. So far as I recollect, Sydenham did not even envisage the possibility that study of the variations of prevalence of continued fevers might throw light upon the means of *preventing* them ; he expected only to learn how the *treatment* of patients should be changed as the "epidemic constitution" changed. Dozens of official reports written in the last eighty years by men far inferior to Sydenham in intellectual ability, have hammered home the truth that upon the safeguarding of communal water and food supplies, freedom from these continued fevers mainly depends. The practical advantages which have been derived from this specialisation and limitation of objectives have been great but they have been purchased at the price of renouncing the larger ambitions of our predecessors. In

contemplating the practical successes of sanitary administrators, the decline in mortality from Typhoid Fever, for instance, which has been associated with the modern method of assimilating the investigation of an "epidemic" to the trial of an accused, some have recalled the words of the panegyric on Julius Cæsar—"Cum alii laudibus ad coelum res tuas gestas efferent, alii fortasse aliquid requirent, idque vel maximum." One tends to judge by results, and the pragmatic value of official reports on Influenza, the results of individual and communal action in mitigating that herd sickness, have been meagre. Seventy years ago Scarlet Fever was a greater scourge than Diphtheria and, during these years, we have learned much more of the intimate biology of Diphtheria than of that of Scarlet Fever, yet Scarlet Fever is no longer what Diphtheria still is, an important cause of death. It seems that over a wide field of human experience our knowledge of the mechanism, the general ætiology, of herd sickness is still rudimentary, that we have not yet substituted for the formal solutions of Galen or Sydenham any adequate scientific solutions.

Experimental epidemiology is an attempt to obtain, by applying to herd sickness the method which has been so successfully applied to the elucidation of problems of individual sickness, knowledge of the fundamental principles determining the ebb and flow of communal sickness. Not even a Hitler or a Mussolini can control at pleasure all or even a large number of the factors possibly relevant to the evolution of sickness in a town or nation. It is possible for a biologist to standardise the conditions of living of a herd of mice, to introduce into it a *materies morbi* and to note what happens over a period which, on the time scale of mice, amounts to centuries of human experience. It is true—and a truth never to be forgotten—that a herd of mice and a nation of men are very different groups, but it is probable that from our observation of the—at least conceptually—simpler herd, we may derive hints for the appropriate interrogation of the more complex herd.

Since the War, experimental epidemiology has been intensively studied in Germany, in the United States of America and in England. I propose to examine in this essay a few of the results which have been reached and to mention some of the problems which have been discussed.

The vast majority of studies in experimental epidemiology have been based on collections of mice. The mouse is a conveniently short-lived animal. Under exceptionally favourable conditions, about half of those born are dead at the end of 22 months.[1] The

[1] Greenwood, *Journ. of Hygiene*, vol. XXVIII, 1928, p. 279.

mice upon which that measurement was made were not run together in a herd and it is not easily practicable to make such observations upon large numbers of herded mice. A study of a herd of mice not exposed to infection and carried on for some 200 days led, however, to the conclusion that the rates of mortality were somewhat but not very much higher than in this favourable case.[1] The comparison is illustrated in the first table where a method of comparison is used, which will hereafter be found convenient.

TABLE I

EXPECTATION OF LIFE, LIMITED TO 60 DAYS

Cage Age in Days	Mice in Herd	Segregated Mice (day 90 = day 0)	Cage Age in Days	Mice in Herd	Segregated Mice (day 90 = day 0)
0	56·79	59·36	65	58·44	59·63
5	57·37	59·53	70	58·62	59·55
10	57·12	59·71	75	58·81	59·47
15	57·05	59·67	80	58·83	59·40
20	56·79	59·86	85	58·64	59·31
25	56·72	59·84	90	58·45	59·22
30	56·69	59·83	95	58·86	59·59
35	57·65	59·79	100	59·12	59·53
40	58·30	59·73	105	58·96	59·47
45	58·42	59·91	110	58·99	59·86
50	58·37	59·85	115	59·27	59·80
55	58·52	59·78	120	59·15	59·73
60	58·47	59·70			

What actuaries call the complete expectation of life at any age is the arithmetic average of the sum of time units lived by all animals entering the age from that age until death. It can only be determined precisely if the fates of a sufficient sample of animals have been followed from the proposed age down to death; even with short-lived animals such as mice this would mean some years of observation. We might, however, summarise the experience of more limited observation by a limited expectation of life, an expectation limited to n time units. We should then need only n time units of observation beyond the oldest age chosen. The maximum possible value of this measure will, of course, be n time units. In the table are shown the expectations of life for 60 days from each of the ages tabulated of mice kept in a herd free from infection and of the segregated mice already mentioned. As the herded mice were not new-born animals but of an average age of about three months, *i.e.* a cage, or herd, age of 0 days corresponds to a real age of about 90 days, comparison is made with the expectations of

[1] Greenwood, Topley and Wilson, *ibid.*, vol. XXXI, 1931, p. 403.

segregated mice beginning at that age. It will be seen that at a cage age of 0, the herded mice enjoyed an expectation of a little more than 3 days short of the theoretical span, while the segregated mice only came short to the extent of 0·64 days. At a cage age of 50 days the former fell short by 1·63 days, the latter by 0·15 days. Since these values are based upon small numbers, a few hundred, of observations they are subject to errors of sampling and, as the distributions are asymmetrical—the modal value of the frequency is near the upper end of the distribution—these errors are not precisely measured by the conventional elementary tests of "probable error." It will not, however, be necessary to discuss these technical minutiæ; for the present purpose it is enough to say that the uninfected herd enjoys a mortality not very greatly in defect of that of the segregated animals and consistent with a span of life of between 2 and 3 years. It would not be far from the truth to say that in terms of total duration two months of a normal mouse's life are equivalent to five years of human existence. As will soon appear, a mouse-generation in infected quarters is a still smaller fraction of human time, its limited expectation in the above sense, nearer 20 than 60 days. It is clear that a community of mice kept under observation for two years must from one point of view, that of the epidemiological history of mice, give us more than as much information as 60 years' continuous study of a human community would provide about the secular evolution of epidemics of men. That is a principal argument in favour of choosing mice as experimental material. It ought not to be necessary, but perhaps *is* necessary, to add that this great advantage is purchased at a considerable price. Epidemiological conclusions which hold for mice may not hold at all for men. It is, in fact, quite certain that some do not; the biological susceptibility of mice to various *materies morbi* is not the same as that of men, mice in an infected herd live under conditions less favourable from the sanitary point of view than those even of an urban slum. Therefore when experiment seems to justify certain epidemiological inferences with respect to mice, we must only generalise them to human herds with the utmost caution. *Comparaison n'est pas raison.*

In the practice of the English experimental epidemiologists, while in most of the experiments no attention has been paid to the genetic purity of the strains of mice used, great attention has been given to the prevention of accidental infection. When an infectious disease has been set going in a herd the herd is only recruited by the admission of immigrants rigorously quarantined and, in the course of more than ten years' continuous work by Topley and his

associates, work which has involved the use of many thousands of animals, accidental contaminations have been rare.

Since I do not propose to refer to the subject again in this paper, it will be convenient to say what I have to say on the question of genetic purity at this point.

I do not think it can be doubted that genetic variations in powers of resistance to disease occur; indeed, the existence of such variations has been made probable for man himself as well as many other species. Hence it is by no means fantastic to suppose that strains of mice or men might be bred immune from particular diseases. Further, it must be recognized that, if we make this admission, it follows that when we work with genetically undefined stock there is in operation an uncontrolled factor, the unchecked influence of which may, indeed must, blur the picture. But it is not to be denied that the epidemiological history of such a community as the English nation is the history of a mongrel stock and that it is difficult, I think impossible, to explain the vicissitudes of the great killing infectious diseases during the last eighty years, for which our information is reasonably exact, in terms of genetic selection. Eighty years ago, the great killing diseases of the acute class were Smallpox, Typhus, the Typhoid Group, Measles, Whooping-cough, Influenza, Scarlet Fever, Diphtheria. Excluding the first three, which assuredly have been modified by deliberate communal action, we may say of the remainder that Influenza is not less deadly, is perhaps more deadly than eighty years ago; that under the other headings there have been improvements, but that the greatest of all those improvements has been with respect to Scarlet Fever. In 1851, 13,634 deaths were ascribed to Scarlet Fever in England and Wales; in 1931, 540 deaths were so ascribed. This immense change is not, so far as appears, due to a decreasing prevalence of the infection; Scarlet Fever is still a common disease occurring in epidemic waves. It is not, so far as appears, due to any conscious application of scientific knowledge. We know far more of the biological mechanism of diphtheria infection than of scarlet fever infection; we have possessed for many years efficient means of both individual and epidemiological prophylaxis in Diphtheria. Yet Diphtheria remains, although a less, a much less, serious cause of death than a generation ago, still a formidable disease. Scarlet Fever is, in this generation, a mere *magni nominis umbra*. There has been what the older epidemiologists would have called a change of epidemic constitution. It is theoretically possible that, under the changing conditions of communal life over the last three generations, that genetic constitution which was resistant to Scarlet Fever

had a survival value, but it is, I think, very difficult to reconcile the disparities of the records of these various diseases with any hypothesis of *general*, non-specific, genetic immunity. Hence, it seems that if we are to use herds of mice as models or indicators of the *kind* of epidemiological evolution occurring in the human herd, it is reasonable to study the changes in a genetically mongrel herd first of all, rather than to begin with animals forming a group biologically very unlike the human population in England of the third decade of the nineteenth century when, after more than a generation of mildness, Scarlet Fever again took a dangerous turn. Of course, this does *not* mean that the genetic factor of herd sickness is unimportant; it must be studied closely, it only means that the, if the reader pleases, cruder comparison should be made first.

The first result of experimental epidemiology has been to reproduce successfully, on the time scale of mice, that picture of varying epidemicity which the record of any human community provides. The story of an experiment continued without break for nearly five years, that is, on the time scale of mice, for very much more than a century of human life, will illustrate the point. The herd was formed on March 5, 1921, out of 26 survivors of a previous experiment in which the biological subject matter was a *Pasteurella* infection. Down to April 30, 1923, 3 healthy mice were added daily to the group and from that time until the end of 1925 only 1 mouse was added daily. During the first five months of the experiment the daily deaths almost balanced the addition so that the population hardly increased.[1] Then mortality declined and by October 8, 1921, the strength of the colony was 182, seven times the original number; a change equivalent to that affecting the English population between 1700 and 1911 and, like that change, concentrated in the last portion of the interval. Then there was a turning-point, mortality increased; by March 4, 1922, the herd numbered 50, it decreased still further, down almost to the original 26, then improved and on May 1, 1923, the population was 58, rather more than twice the original number. If a year of mouse life is taken as equivalent to 30 human years, this phase would be equivalent to 65 years of human experience. The average population was 63·5 and the mean immigration rate 4·72% per diem. At this point, the immigration law was changed, in future only 1 mouse was admitted daily. At first the population increased, and numbered almost 70 in July 1923. But mortality again increased,

[1] It should be mentioned that any mice born in the herd and not devoured by their parents were removed. Any population increase was always due to immigration; there was no natural increase.

the population fell rapidly, actually to 22, fewer than the original number, but recovered again and on March 14, 1925, amounted to 81. Again there was a sharp epidemic, the population fell rapidly, to less than 20, but again recovered to 40 in the month of July and remained near that level until the end of the year; on December 31, 1925, the census return was 42. From May 1, 1923, to December 31, 1925, in mouse time, would in human time be 80 years; in that period the population decreased from 58 to 42; the rate of mortality had decreased but not sufficiently to compensate the decrease in number of immigrants.

Such is the crude statistical history of this herd. I pass to its biological history. During the first year of observation, the disease we were studying, *viz* pasteurellosis (a disease mainly conveyed by respiratory droplet infection and having some vague analogy with human influenza), was not only the reigning but practically the only death-producing disease. But at the end of the year one of the comparatively few failures of our technic gave us an instructive experience. *Bacillus ærtrycke* (Mutton) (the biological *materies morbi* of a disease of intestinal type, having certain, again vague, analogies with the human typhoid group) was introduced by immigrants. This was, so far as the herd were concerned, a literally "new disease" and as a killing agent completely superseded *Pasteurella*. Between June 27, 1924, and January 5, 1925, no deaths at all were chargeable to pasteurellosis. Now, as, on the human time scale, that would have been an interval of some 15 years, public health officers in such circumstances might reasonably have congratulated themselves on the final extinction of pasteurellosis. But a mouse dead on January 5, 1925, exhibited the pathological stigmata of both *Pasteurella* and *B. ærtrycke* infection. The reigning type of illness changed, on March 12, 1925, a fresh series of deaths attributable to pasteurellosis began and continued for a little less than 3 months or say 7½ years of human life. *B. ærtrycke* then resumed control and from June to the end of 1925 only one death (on December 14, 1925) was attributable to pasteurellosis. This period of intermission is by no means the greatest in our experience. In another herd where the two infections had been introduced, there was an interval of 325 days between successive deaths from pasteurellosis and the last survivor of the first epidemic period had died 17 days before the new epidemic of pasteurellosis began. It must be emphasised that this latter infection has never been introduced in the body of a healthy immigrant. We see therefore in the herd of mice phenomena similar to those observed in a human herd, waxing and waning of rates of mortality, the rise

and fall of "new" disease. "And so," wrote Sydenham, "I think myself justified in holding that diseases have periods set to them by divers hidden and so far uncomprehended changes in the very bowels of the earth, dependent on her age and duration, so that even as some diseases which once flourished have now either wholly died out or at least are well stricken in years and appear but seldom (of such are leprosy and not a few others), even so those diseases which now flourish will in their turn pass away giving place to new species respecting the nature of which we cannot form the least forecast."[1] The succession of pasteurellosis and ærtryckial infections in the experiment just described illustrates the phenomenon which, however, we need hardly attribute to terrestrial changes in Sydenham's sense but can more plausibly attribute to variations of what is now usually spoken of as herd immunity.

Let us now consider a little more attentively what is happening in such a herd starting from any point of time. The members of it at that instant will consist of some veterans who have survived many days and have already tasted the infection. Some of them will be immune (either because they are so genetically constituted as to be able to ignore the *materies morbi*, or because sub-lethal doses of infection have made them resistant, *vid. inf.*), others will be sick unto death and will die in a few more days. Then there will be younger mice, some of whom have not yet been infected at all. Into this herd enter young mice which have never been exposed at all to the infection, new chums. If the daily rate of mortality of the herd is plotted, the graph shows plateaux, valleys and peaks, corresponding to the steady, falling and rising population of the group. *Why* do these variations occur? Evidently if we were to add daily to a community subject to a constant rate of mortality a fixed number of entrants, the population would speedily decrease or increase to a constant number, the number being of course such that its losses by death at the assumed constant rate were just compensated by the fixed number of accessions. Although the death-rate of male members of the middle class at ages between say, 35 and 65 years, has improved through the seventy to eighty years during which exactly 15 ordinary fellows were elected annually into the Royal Society of London, it will be found that during that period the strength of the Society did not vary much. In the herd just described the fluctuations were, as we have seen, very great. The simplest explanation which suggests itself is that an epidemic is generated when the proportion of susceptibles to the whole population has reached some critical value. Take

[1] *Obs. Med.*, vol. V, No. 4, p. 15.

the case of Measles. This is a disease which is taken by a large proportion of all children born in England, and in London epidemics of Measles occur with great regularity at intervals of not quite two years. When an epidemic occurs in a crowded district a large proportion of the children in the neighbourhood who have not already had Measles go down with it. Then instant by instant the population of children who have not had Measles is increased and finally—to use a hackneyed and really inappropriate metaphor —the heap of inflammable material is ignited and the disease again burns itself out. That is a mere metaphor—the use of metaphors, by the way, is one of the curses of epidemiology—but years ago Sir William Hamer showed that at least a good many of the facts could be soberly explained in terms of rise and ebb of susceptibles. Quite recently the late H. E. Soper[1] re-investigated the matter. He pointed out that if a community receives a steady accession of susceptibles, and if each sick person can infect one or more susceptibles in an instant of time, then taking the incubation period as the unit of time, the number of cases in the next interval will be equal to the number in the previous interval multiplied by the ratio of the number of susceptibles available to some multiple of the number of susceptibles added per unit of time. When the number of susceptibles added is precisely equal to the number of new cases generated, there will, of course, be no oscillations, but when this equilibrium is disturbed slightly, the prevalence will begin to oscillate cyclically. The greater the disturbance the longer the period of oscillation. This quite simple hypothesis explains a good deal but *not* the whole of the facts of measles. It does not, however, explain what happens in an experimental herd. To mention only one reason, the size of the herds is so small and the variations of mortality so large, that the mathematical conditions implied in Soper's hypothesis are not fulfilled. Returning to the original notion, it has not been our experience that a violent epidemic breaks out when the proportion of young mice has reached some definite critical value. Since, as will shortly appear, young mice die at a much higher rate than old mice, it is a mere truism to say that when mortality is low there are many young mice in the herd. Something more useful than this, such as a prediction formula enabling us to tell from the age composition of the herd whether an epidemic be imminent, we have not, so far, discovered. We have, however, discovered this. That in general (exceptions have occurred) the interval between peaks of mortality shortens the larger the number of mice added daily, *but* large discontinuous

[1] *Journ. Roy. Stat. Soc.*, vol. XCII, 1929, pp. 34–91.

additions are less unfavourable than continuous additions. If, for instance, we have decided to add 1,000 mice to an infected herd, in the course of 100 days, then the addition of 10 mice a day throughout the period is likely to be associated with much higher mortality than adding batches of 100 every 10 days. Although the phenomena cannot be described in terms of such simple data as age constitution, it does seem that epidemicity, the time of emergence of a great excess mortality, is some function of the inter-actions of members of the herd, sub-groups of the group, at different stages of susceptibility. Perhaps if it were possible, as, of course, it is not, to experiment on a scale so vast that the chance of individual events taking control would be negligible, then the regularity of the phenomena would become manifest. One seems to need a *range* of susceptibilities all represented at once in some unknown proportions for the stage to be set for an epidemic.

To understand this conception we must examine such an experiment as that just described from a different angle. We have so far looked at the herd from the ordinary historical point of view, but we might have looked at events in it from the point of view of seniority in the community, *viz.* not have asked what was the death-rate (or the population) on such and such a date in the year 1923, but what was the death-rate among mice which had survived so and so many days in the community, or of 100 mice which entered this community at some time during the continuance of the experiment how many were still alive at the end of 1, 2, 3, etc., days? In this method of examination, secular variations are smoothed out and we examine the *average* change in resistance of the group as the time of exposure of its members grows.

What is invariably found is that after entrance to an infected herd the rate of mortality rises more or less rapidly to a high maximum and then decreases to a level much above the mortality experienced by normal mice (*i.e.* by mice of the kind referred to at the beginning of the paper). Thenceforward it fluctuates about the level showing no significant tendency to rise above or sink below it. Table II illustrates the points. Its second column is based upon the first phase of the experiment above described, *i.e.* upon a herd infected only with pasteurellosis. Its third column is based on a herd infected with disease due to *Bacterium œrtrycke*. It will be found that the herd age of maximum mortality is not the same in the two types of infection; both, however, agree in the general form, *viz.* a mono-modal curve asymptoting to a value much above the rate of mortality of mice not exposed to risk of infection. It is, however, necessary to remember that as age in herd increases

the number of animals under observation must decrease, so that the sampling error to which any statistical constants are subject increases and, even in studies such as these for which many thousand mice have been used, rates of mortality at ages in excess of 100 days in herd are usually subject to too large errors of sampling to be reliable. Our experience is not wide enough to permit us to say that in the resistance of those who have survived exposure more than n days, where n is large, *no* further change occurs, so that the population dies out logarithmically. We can only say that the hypothesis describes such results as we have reached.

Now one comes to the really exciting question—*how* do these things happen? On paper, we can give two quite different plausible

TABLE II

Cage Age in Days	Probability of Dying between Cage Age x and Cage Age $x + 1$ Days		Cage Age in Days	Probability of Dying between Cage Age x and Cage Age $x + 1$ Days	
	(1)	(2)		(1)	(2)
0	·022	·004	17	067	031
1	·033	·005	18	·078	·032
2	·037	·003	19	068	·043
3	062	·005	20	·068	·038
4	·060	·006	21	·064	·054
5	·064	·006	22	·068	·054
6	·069	·011	23	·051	·068
7	·054	·014	24	·041	·065
8	·065	·013	25	·032	·070
9	·066	·016	35	033	·022
10	·048	·022	45	·026	·021
11	·054	·021	50	·020	·006
12	·053	·022	60	·038	·014
13	·067	·019	70	·022	·003
14	·066	·030	80	·051	·004
15	·087	·032	90	·025	·014
16	·071	·029			

answers. We might on the one hand say that the innate powers, the genetic constitutions, of the entrants vary widely, that the least resistant are on the average the first to die and that ultimately we have a population of survivors of approximately equal resistances; these, under the averaging conditions of the method of presentation, will then die "by chance," that is logarithmically. On the other hand we might deny any differences of innate resistance and say that by chance sub-lethal infections some of the entrants acquired an active immunity, that such immunity reaches a critical value and that when this is attained we have a popula-

tion of practically equal resisting powers which will die off "by chance."

No scientifically-minded person could possibly hold either opinion to the exclusion of the other; both factors, or sets of factors, must be involved. At the most we can try to ascertain which is likely to be the more influential. The following was an attempt to answer this latter question. Two herds were formed the members of which I shall call A and B mice, each herd was based on a nucleus of *Pasteurella* infected mice, but while the A herd was only recruited from healthy mice, the B herd received both healthy mice, let us call them C mice, and mice which had survived a greater or less time in herd A. The experiments were on a considerable scale, 1,484 mice died in herd A and 2,734 in herd B. In herd B the number of days of observation on A mice was 26,909 and on C mice 28,804 (in this method of enumeration a mouse which has survived n days contributes n to the grand total; it is perhaps the most satisfactory method of statement). Evidently the A mice entering B have, in comparison with the C mice, an advantage and a disadvantage The advantage is that, on the hypotheses mentioned, they should either have acquired some active immunity against the infection during their membership of A or have in that herd suffered selective elimination. The disadvantage is that some of them may enter B already mortally sick and so die without responsibility attaching to the environment in B.

As appears from Table III on balance A mice had a decided advantage in herd B over C mice.

TABLE III

	Length of Exposure in A (Days)	Number in Group.	Percentage surviving at least 28 Days in B
C mice .	0	887	23·3 ± ·96
A mice . . .	10	173	26·7 ± 2·27
	20	163	36·0 ± 2·54
	30	128	46·8 ± 2·98
	40 & 45	90	49·7 ± 3·55
	50 & up	131	55·6 ± 2·93

Is this advantage more likely to be due to a weeding out of the susceptibles in A or to immunisation effected there? If the former it would seem reasonable to suppose that if during their sojourn in A the transferred mice had been exposed to a very low death-rate, then their advantage in B in comparison with the C mice

would be less than the average of A mice, since the stringency of selection would have been less. The average daily death-rate in herd A was 23·7 per 1,000. If we use as a standard of comparison the convenient measure referred to at the beginning of the paper, the limited expectation of life, taking 60 days as the limit, then in herd B the C mice had an expectation of 22·37 ± 0·36 days (as compared with the theoretical 60 days) and the A mice an expectation of 28·43 ± 0·55. If now we restrict our comparison to transferred mice which while in A were never exposed to a daily rate of mortality above 7·55 per 1,000, or one-third of the average, the results are those set out in Table IV.

TABLE IV

A Mice whose Time of Exposure in Cage A was at an average Death-Rate of < ·00755 and C Mice

	Length of Exposure in Cage A (Days)	Number in Group	Length of Life in Cage B limited to 60 Days	
All C mice	0	887	22·4 ± ·36	
C mice corresponding to those A's	0	493	20·9 ± ·49	
A mice	10	59	23·3 ± 1·60	All A mice 25·1 ± ·84
	20	38	23·8 ± 1·99	
	30	39	25·4 ± 1·97	
	40	30	26·6 ± 2·24	
	50	9	34·6 ± 4·10	
	60	10	33·7 ± 3·89	
	65	9	22·4 ± 4·10	
	70	8	31·5 ± 4·35	
	75	10	14·9 ± 3·89	

∴ Difference between these A's and all C's = 2·78 ± ·92 days.
Difference between these A's and *contemporary* C's = 4·2 ± ·97.

Even when exposed to a relatively slight selection the mice which had had experience in A showed to advantage. This argument in favour of immunisation rather than selection as the factor of advantage is not, however, free from objection. I have already mentioned the difficulty that mice transferred from A may be bringing with them a fatal infection; these cases may be presumed to be most numerous when the severity of the disease in herd A is greatest. But as we see the advantage of the A's over the C's is rather greater when the transferred mice had passed through a severe exposure than when they had been less severely tried. Hence if allowance could be made for the moribund transfers it might be found that there *was* a very decided superiority in the resistance

of the mice which had been stringently selected, *i.e.* that the comparison favoured the selection rather than the chance immunisation hypothesis. On the other hand can be urged the fact that there is no regular correspondence between the increasing advantage of transferred mice and the increasing length of sojourn in herd A. There seems no theoretical reason why the advantage conferred by selection should not continue to grow with duration of the selective process, but, as will shortly appear, it does not seem possible by active immunisation—at least in the infections under notice—to raise the level of immunity beyond a comparatively low critical value.

An elaborate statistical attempt to settle the matter has been made. It has been found that while the correlation between length of life in herd B and length of life in herd A, holding the death-rates in A and B constant, was significantly positive, the correlation between length of life in B and death-rate in A, holding length of exposure in A and death-rate in B constant, was insignificant. This result has been confirmed on the very extensive data of the long experiment already described, in which the period of adding 3 mice a day took the place of the present A herd, and the period of adding 1 mouse a day that of the B herd. There is indeed no doubt that duration rather than severity of exposure is statistically the more important variable. But it cannot be said that a clear-cut conclusion has emerged. The balance of evidence inclines in favour of the immunisation hypothesis, but the scale is not tipped over decisively. There is, particularly in the admirable studies of a semi-closed human community made by Dudley,[1] very cogent evidence that either natural or artificial induction of immunity against the infection of Diphtheria will result in greatly raising the herd level of immunity in a group recruited casually. The effect reaches a level such that the infection, as a clinical illness, may be banished from the community altogether. In herds of mice, with the infections we have used, that result has never been reached, probably because the environmental conditions are far too unfavourable. Perhaps we may think of the events in a herd of mice as of the following order. The immigrants come into a highly infected community, they are subjected to a steady bombardment of infective material and may receive in a unit of time 0, 1, 2, 3, etc., shots or quanta of infection. The mice which receive in the first unit time exposure more than some limiting number of quanta—the limiting number will be a function of natural resistance—die sooner or later, whatever else happens to them is a matter of indifference,

[1] *Med. Research Council,* S.R.S. No. 111, 1926.

they are doomed. But the fate of those who receive less than the critical dose, will depend on their subsequent experience. Suppose that for mice of a particular genetic constitution n quanta received in one and the same time unit are a fatal dose; it does not follow that, if $n_1 + n_2 = n$, a mouse which received n_1 in the first and n_2 in the second of two successive intervals would die, it does not even follow that the succession n_1 followed by n_2 will produce the same immunological result as the succession n_2 followed by n_1 if n_1 and n_2 are unequal.

The "law" of infection here postulated is a very simple one. If a group were indeed exposed to continuous bombardment then at the end of a unit of time the proportions hit 0, 1, 2, 3, etc., times would be given by the terms of :—

$$e^{-\lambda}\left(1 + \frac{\lambda}{1!} + \frac{\lambda^2}{2!} + \frac{\lambda^3}{3!} + \ldots\ldots\right)$$

where λ is a constant parameter. Evidently if all hit once or more often in the time unit perished the survivors would form a simple decreasing geometrical series. If we postulate a greater minimum critical value than one hit, the decrement will at first be slower than this. Suppose, for instance, that those hit twice or more often die. The succession of survivors will be

$$e^{-\lambda}(1 + \lambda),\ e^{-2\lambda}(1 + 2\lambda),\ e^{-3\lambda}(1 + 3\lambda), \text{etc.}$$

The ratio of the rth to the $(r - 1)$th term is $\dfrac{e^{-\lambda}(1 + r\lambda)}{1 + (r - 1)\lambda}$. This will diminish toward $e^{-\lambda}$ with increasing r. As we have seen, the rate of decrement does ultimately tend to become geometrical *but* the ultimate rate of decrement is far smaller than that observed at an earlier stage of herd life. No plausible modifications of this hypothesis which retain λ as a constant have been found to describe the facts satisfactorily. If, however, we permit λ to vary there is no difficulty in describing the facts, but there is also no particular advantage since, unless we have some reasonable hypothesis of the "law" of change of λ we reach a mere arithmetical identity. The "law" of mortality as a function of seniority in herd is still undetermined.

Passing now to the effect of pre-immunising mice admitted to an infected herd, the results in one particular case, that of herd infection with *B. œrtrycke* have been sufficiently striking. They are illustrated in Table V.

TABLE V

Probability of Surviving 5 Days

Cage Age in Days	Specific Deaths			
	E, F, G	Controls	Difference	Column 2 / Column 3
0	·9968	9925	·0043	1 004
5	·9946	9715	0231	1·024
10	9679	9151	·0528	1·058
15	9351	·8291	1060	1·128
20	·8261	6909	1352	1·196
25	7164	·5691	1473	1·259
30	·7053	·5875	·1178	1·201
35	·8004	·6813	1191	1 175
40	·7619	7270	·0349	1·048
45	8121	·6984	·1137	1 163
50	8295	8210	·0085	1 010
55	8786	8590	·0196	1·023

These calculations are based on specific mortality only, *i.e.* upon deaths due to infection with *B. œrtrycke*, deaths due to other causes have been ignored. The meaning of the second and third columns is that of the mice termed E, F, G, for instance, 99·68 per cent. of those who enter the herd will survive 5 days, 71·64 per cent. of those who have survived 25 days will live another 5 days and so on. E, F, G mice are mice which before admission to the herd had been artificially immunised. Vaccine E was a broth culture of *B. œrtrycke* in the normal smooth phase, incubated for 24 hours at 37° C. and then killed by the addition of 0·25 per cent. formalin followed by heating to 55° C. for 1 hour. It contained the O and the H antigen in the type and the group phase. F was a saline suspension of *B. paratyphosum B.* smooth in the group phase, killed in the same way. It contained the O antigen common to *B. paratyphosum B.* and to *B. œrtrycke* and the H antigen shared by these species in the group phase. G was similar to F except that the strain selected was in the type phase and the only antigenic constituent of this vaccine represented in *B. œrtrycke* was the O somatic antigen. The suspension to be inoculated was diluted to contain $1{,}000 \times 10^6$ bacilli per c.c., and 0·5 c.c. of this was injected intraperitoneally. One week later the injection was repeated, using the same dose and the mice were added to the experimental cage on the seventh day after the second inoculation. An experimental herd was formed by infecting 50 mice with *B. œrtrycke*, adding to them 50 normal mice and thereafter adding 3 normal mice daily (the experiment was continued from 4.i.1928 to 17.ix.1929). The inoculated mice were added in batches of 10 every seventh day and

with the inoculees a batch of normal mice was added. For the purposes of the present discussion the fates of these controls did not differ sufficiently from those of the mice added daily for separate tabulation to be needed.

Looking at the table it will be seen that the advantage of the inoculated mice increases to a maximum and then by the fifty-fifth day has almost sunk to parity. The advantage is greatest at the period of herd life when the risk of death is heaviest. Put in another way, using the measure of limited expectation, we know that in an uncontaminated herd the rate of mortality is so low that the average length of life during the first 60 days' exposure is only 3 days short of the ideal 60. In the controls entering *this* herd it was only 27 days or less than half the proper expectation. In the immunised mice it rose to 35 days. In this experiment unsalted mice were admitted to the herd and this might militate against the chances of the immunised. So a herd was started in which, after carrying the experiment on with unsalted additions for some time, immigration was restricted to immunised mice only. During this latter period the immunised animals fared exactly as in the previous experiment. When the daily immigrants numbered 3 the limited expectation of life was 34·9 days, when only 1 mouse was admitted daily it reached 36·4 days.

It is clear that the immunised animals enjoyed a considerable advantage, an advantage which would have been very striking indeed had their exposure to risk been limited. Suppose, for instance, that at the end of, say, 50 days, the survivors of the controls and the survivors of the immunised animals had been removed from their pestiferous environment, how many out of equal numbers, say two batches of 1,000, would there have been to remove? By continued multiplication of the entries in the second and third columns of Table V we reach the answers 185 and 58. More than three times as many immunised animals would live to be removed. This result is again consistent with human experience in respect of bacterial infections. There is, I think, no doubt that when individuals or groups are exposed to intense risks of infection for comparatively short periods, artificial pre-immunisation has been very successful. Instances would be the experience of troops on active service with regard to the typhoid group of infections and to cholera. It is not, however, equally certain that pre-immunisation will eliminate a disease from an undying corporation exposed, generation after generation, to unfavourable environmental conditions. It is, however, true that, with the doubtful exception of smallpox, artificial pre-immunisation has never been carried out

generation after generation on so wide a scale as to provide an adequate test. We must recollect that, in the experimental herds, the continuously incurred risks are enormous. The filthiest slum of an industrial town a century ago was a health resort in comparison with our herds of mice.

Although the experiments described do not suggest that, for the particular infection used, pre-immunisation is likely to attain complete success—that is to put the immunised into the position of being able to ignore any stress of infection to which they may be casually subject—the general trend of the work is, in many ways, encouraging. It seems that in diseases of the virus group—of which Measles is a striking example—more may be expected. This work, however, has not yet reached a stage at which it can fairly be discussed in a general paper

Although this work has now been carried on in America and England for a good deal longer than ten years, it is but in its infancy. It is open to a pessimist to say that, so far, little more has been achieved than the reproduction in herds of mice of results which have some analogy with what had been observed through generations in human societies. I hope to have shown that rather more than that has been done, but if *only* that had been done, it would have been a good deal. It is a good deal to have brought the study of another group phenomenon within the range of experiment; to do so has required much patience and the overcoming of many unexpected difficulties. The instrument, the technical method, is now fairly workmanlike. Some results have been reached; many more and more important ones will surely be attained.

REFERENCES

The literature of Experimental Epidemiology is already fairly extensive. A general review of it is contained in Bijl's report to the Netherlands Public Health Department (*Verslagen en Medeelingen betreffende de Volksgezondheit*, No. 6, 1930). A study mainly from the standpoint of the English workers is contained in the present writer's *Epidemiology, Historical and Experimental*, being the Herter Lectures for 1931, published by the Johns Hopkins Press. Most of the original papers by the American workers have appeared in the *Journal of Experimental Medicine* and most of the papers by Topley and his collaborators have appeared in the *Journal of Hygiene*.

CHEMICAL ENGINEERING AND ITS INDUSTRIAL SIGNIFICANCE

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Science and Industry

The widespread development of scientific research, particularly during the past quarter of a century, has profoundly affected every branch of manufacturing industry. It has greatly augmented the technical resources of the manufacturer and multiplied his opportunities; but it has completely altered his outlook, and it has led to drastic and far-reaching changes being made in the whole organisation of industry.

The old-time manufacturer was generally a practically-minded man who believed, with good reason, in well established rule of thumb methods and was in all his business dealings a convinced individualist. The peculiar knowledge upon which he depended for the improvement of his processes or the initiation of new ones was largely the product of a kind of inspired empiricism, practised by a long succession of closely observant and highly intelligent craftsmen The knowledge so gained was jealously guarded from all his competitors. It was this inspired empiricism which led to England's industrial development and ascendancy in the pre-scientific manufacturing era which opened over a century ago with the introduction of steam-driven machinery.

To-day, however, mere empiricism, however inspired it may be, is not enough. Natural ability and ingenuity must be reinforced by the possession of a sound and extensive knowledge, both of the scientific principles which lie at the back of every manufacturing operation and of the best way of applying these principles to the solution of all kinds of industrial problems. Every industry to-day must be equipped with science at all points, if it is to survive, let alone prosper!

Not the least significant result of the impact of science upon industry is the change it has produced in the organisation of industry

and in the outlook of the manufacturer himself. This is to be expected, since science is essentially the embodiment of the co-operative spirit, whereas industry is organised upon a competitive and individualistic basis. The new ideas and developments upon which the individual manufacturer depends for his continued progress and prosperity arise no longer entirely within his own establishment and out of the peculiar skill or knowledge of his own craftsmen. More often than not, they are the outcome of researches that may have been carried out in Japan or Russia or America or even in the laboratory of one of his competitors. For science is served to-day by hundreds of thousands of workers throughout the world, who recognise no distinction either of race or locality or tongue. Some work in industrial laboratories upon problems which are closely related to manufacturing conditions and needs ; others in university laboratories investigate problems of a more fundamental character, which, if not of direct importance to the manufacturer to-day, may be so to-morrow. Each worker is prompted by an unbiassed desire for knowledge. The results of his work are widely published and are placed freely at the disposal of all who are able to make use of them.

Thus, instead of employing an inspired empiricist to secure a temporary advantage over his competitors, the manufacturer now engages a staff of scientifically trained men who ascertain what has been done by research workers throughout the world and apply the results of this work to their immediate problems in order that their employer may keep his processes continually abreast of the rapid advance of science. If, by their own researches, they can get a little ahead of the rest of the world, so much the better, but it will take all their scientific knowledge and operating skill to maintain that advantage for any length of time. For not only does the manufacturer now derive new ideas from without instead of from within, but they shower upon him on all sides with almost embarrassing frequency. A sea of scientific information rises about him and his competitors alike. It provides him with an opportunity which he dare not ignore, for it is also a menace. He must seize it before it overwhelms him. It sets a pace which he must follow ; it makes demands which he must satisfy.

The task of guiding an industry successfully through the rapidly changing conditions of the modern world calls not only for vision and courage of a high order, but needs large financial resources. An effective research staff and a well considered research programme have become *sine qua non* in any well-organised industry to-day. The financial resources necessary for carrying out a research pro-

gramme of any magnitude and of putting into effect the recommendations of the research department are generally beyond the means of a small, individual manufacturer. This difficulty is overcome in part by the adoption of a co-operative research scheme, in which a number of manufacturers engaged in the same kind of business contribute to a common research fund and, in return, make use in their own individual factories of the results of the research work. Owing to the demand for the solution of urgent manufacturing problems, as well as for information of a more fundamental character upon which to base plans for the future, co-operative research has already become a well established feature of our industrial life.

Further, it is frequently found that a new process can only be utilised advantageously when it is operated continuously upon a very large scale. The cost of installing and operating so large a plant then becomes very high, while extensive markets must be found to ensure a large and continuous output. This leads to co-operative production and selling.

Finally, the prosperity of any new process to-day may be very short-lived, for at any moment a better process may be discovered. In planning the costing of any industry in a scientifically active world, obsolescence has to be written in capital letters. The cloud hitherto no bigger than a human hand now stretches across the sky and renders the outlook uncertain in the extreme. This greatly increased risk of obsolescence can only be sustained adequately by those who possess ample financial resources, combined with a research and technical staff able to keep themselves and their processes abreast or ahead of all external developments.

Thus, the increasing dependence of industry upon the results and methods of scientific research tends to make it co-operative rather than competitive, both in organisation and outlook.

To us who live in the resulting transition period, science comes as a mixed blessing. It increases the amenities of life, it speeds up transport and it augments the forces of production and construction, but it threatens the security of the individual, whether he be master or man. It may even rob an entire community of a natural advantage upon which its wealth depends. The manufacture of synthetic ammonia and nitrates has seriously discounted the value of their nitrate deposits to the people of Chile. The impact of science has disturbed the very foundations of our social, economic and industrial life, so that a continual series of delicate adjustments will have to be made if the life of the community is to be maintained in a coherent and articulate form.

Meanwhile, individual industries must adjust themselves to the new conditions as best they can. How can this be done?

Firstly, by employing all the resources of science and experience to make a thorough analysis of the peculiar problems both of manufacture and of organisation which are encountered in industry to-day. In the older industries, these problems may arise out of the tendency of an industry to dwell, like Lot's wife, upon the past. In the newer industries, the problems are more likely to be due to a lack of special knowledge or experience.

Secondly, with the information gained as the result of such an analysis, it is necessary so to design the required plant and to plan the conditions under which it is to be operated that the resulting processes shall function with a maximum of efficiency and adaptability.

The Purpose and Scope of Chemical Engineering

Chemical engineering is concerned primarily with the construction, or reconstruction, upon a scientific basis of all so-called *chemical* processes. In any chemical process, a given raw material is subjected to a succession of carefully controlled chemical or physical operations, by which it is decomposed and transformed into an entirely different product. Such a process differs fundamentally, therefore, from engineering or mechanical processes, in which a given piece of material simply undergoes a change of shape or texture without its chemical composition or physical state being affected.

Chemical processes provide the staple of the chemical group of industries, which manufacture acids, alkalies, cement, fertilisers, explosives, dyestuffs, etc., and a large number of comparatively new products, including fine chemicals, drugs, synthetic solvents, resins, foodstuffs, plastics and perfumes, as well as artificial silk, the newer dyestuffs, etc.

But the employment of chemical processes is not confined to the chemical industries. Many of the manufacturing operations with which a chemical engineer is concerned are employed in such diverse industries as mining, smelting, power generation, petroleum refining, lumbering, food manufacture, brewing, the dairy industry and agriculture, the manufacture of textiles, pottery, rubber goods and aircraft, and the purification and control of public water supplies. The chemical engineer, therefore, concerned as he is with the problems and conditions which occur in such a wide range of industries, is exceptionally well equipped to play a leading part in the attempt to endow industry with the scientific spirit and to equip her at all points with a well organised scientific technique.

The chemical engineer owes much to chemistry, to engineering and to economics. He seeks to combine the analytical insight of the chemist with the practical outlook of the engineer and the circumspection of the economist. He is confronted with problems which belong entirely to none of these individual sciences but only arise out of their interaction in the commercial operation of a chemical process. Consequently, he cannot look to chemistry, engineering or economics for a complete and satisfactory solution of his problems. He has to work out his own salvation and, in doing so, he acquires the special knowledge and skill which give him his peculiar value and significance

A chemist is concerned with the behaviour of different molecules and ions under a wide range of conditions, and this provides the necessary starting-point for the chemical engineer. On a commercial scale, however, a process has to be clothed, so to speak, with a plant which will enable the conditions necessary to the reaction—*e.g.* temperature, pressure, chemical composition—to be maintained at every point of the reaction mass. This introduces problems in heat transmission and fluid flow, in the controlled diffusion of some component from one phase to another, as well as in the choice of suitably resistant materials out of which the plant can safely be constructed. Chemical reaction materials are frequently intensely corrosive and the problem of obtaining suitable constructional materials is frequently one of the major problems with which the chemical engineer is confronted

The engineer can construct satisfactory vessels in steel and concrete, but he has to modify his formulæ and his methods when he is forced to use the special constructional materials which are rendered necessary by the chemical requirements of the process. The principles which determine the flow of such simple fluids as air, steam, water or oil are well understood and widely applied by the engineer. The chemical engineer, however, has to design equipment in which liquids of widely different viscosities, as well as powders, slurries, emulsions, dusty gases, mists, etc., have to be pumped and conveyed and subjected to particular chemical or physical treatment. Again, the heating or cooling of such a wide range of materials, intimately bound up, as it is, with their flow characteristics, depends upon a series of additional factors with which the engineer has very little to do.

The rational design of reaction vessels and of mixing and transporting equipment for the variety of materials which a chemical engineer is called upon to handle requires information and data which, at present, do not exist; it is the task of the chemical engineer,

working in co-operation with chemists, physicists and engineers, to obtain this information, both by the methods of fundamental research as well as in the field.

When every chemical and engineering factor has been considered and all the data have become available for constructing a suitable plant, it is still necessary to provide for a number of economic requirements: the direct operating cost, the standing charges, the cost of selling in different markets all have to be met out of the revenue from the sale of the product before the process can show a profit.

Finally, the costing of a chemical process is peculiar. The chemist's ideal yield is rarely the most profitable; it may pay the manufacturer to be content with an 80 per cent. yield rather than strive for one of 90 per cent., for, after all, the final criterion of the success of any commercial process is that it shall earn a profit. Similarly, the requisite quality of the product depends upon the market for which it is intended. The assessment of a chemical plant for depreciation and obsolescence provides a problem that is frequently insoluble.

The special problems with which the chemical engineer has to deal can best be exemplified by considering briefly the way in which chemical processes were planned and operated in their early days. The old-time chemical works was a jumble of independent plants, representing in their varied designs a compromise between the hopes of the chemist and the fears of the engineer. Each plant stood by itself and had its own separate boiler and coal supply. Coal was so cheap that no attempt was made to use it economically. As labour also was cheap, very little thought was devoted to the internal arrangement of the plant so as to economise human time and effort. Men with wheelbarrows and spades simply took the place of the chemist's spatula. The chemists and engineers of those days were wrestling with far greater and more urgent problems of plant construction and process control. The plant required for chemical processes must be constructed of materials that are both strong enough mechanically to sustain the stresses that arise from the mass or momentum of the contents, and adequately resistant chemically to the corrosive action of the reaction materials, frequently intensified by heat or movement. The materials available were restricted to cast iron, mild steel, lead, copper, timber, stoneware, brick and fireclay. The methods of fabrication were correspondingly few and simple, confined to the foundry, the boiler shop and the fitter's bench. There was also very little knowledge of the chemical engineering principles upon which the rational design

of chemical plant can alone be based. The design of each commercial unit adhered as closely as possible to that of the corresponding laboratory apparatus, allowing for the difference in size and the use of iron or stoneware instead of glass as a constructional material.

It is not surprising that these early plants were generally inefficient and had short and uncertain careers. Sooner or later, the reaction got out of hand, either because of inefficient mixing or of irregular heating or cooling, and the whole thing blew up. Often, the product was incurably ferruginous, while the time spent by the numerous workmen in trucking materials about the plant would have destroyed all chance of profit, had their wages not been small and the market price of the product been greatly inflated by a rapidly growing demand.

To-day, everything is altered. Manufacturing costs are higher, competition is keen and markets are difficult to get and to hold. Chemical processes now impose more exacting conditions upon the designer and upon the operator. Success can only be secured by making the fullest possible use of all the resources of science and experience. It is in attempting this difficult task that the special problems arise with which the chemical engineer is peculiarly concerned. Some of these problems may be stated as follows:

(1) The selection, storage and transport of all raw materials and reagents required in the process.

(2) The selection and use of constructional materials which will not only resist the stresses that are set up, but will also minimise any risk of contamination of the product. In some cases it may not be possible to operate the process at all until a suitable constructional material has been found, as, for example, for a process demanding a combination of high temperature with high pressure.

(3) The accurate and continual control of the reaction conditions at every point of the reaction mass.

(4) The introduction, where possible, of continuous methods of operation so as to reduce labour costs to a minimum and also to ensure a better and more uniform product. With continuously operated plant, also, it becomes possible to use automatic methods of control and so to eliminate any variation due to the intervention of the human factor.

(5) The reduction of labour costs by improving the arrangement of the individual plant units, particularly as it affects their operation and control.

(6) The reduction of the cost of steam and power, generally by

centralising their generation and distributing them in a rational way to the different plants requiring them. This is bound up with—

(7) The need for a logical and convenient lay-out of the factory to facilitate transport to and from independent plant units as well as to provide communication between the plant units and the stores, shops and warehouses.

The scope of chemical engineering appears at first sight to be unlimited. The range of possible raw materials is extending rapidly, apparently without limit This is a natural result of the application of chemistry to industry, for, to the chemist, everything is, potentially at least, a raw material from which something quite different may some day be manufactured.

The number and variety of chemical processes also increase continually as a more extended range of operating conditions—*e.g.* higher temperatures and pressures—is made possible by the discoveries of the metallurgist and the engineer. As a direct outcome of this increasing variety of raw materials and processes, there is a corresponding multiplication of new products, many of which are entirely new substances and form starting-points for new industries.

Chemical Engineering an Analysis

It would appear at first sight that any attempt to make a systematic analysis of an almost unlimited range of processes and operating conditions provides at the outset an almost insoluble problem. Beneath this variety of material and multiplicity of processes, however, there is an underlying simplicity. When these chemical processes are analysed, they are found to be made up of certain unit operations, arranged in proper sequence. These operations provide the industrial counterpart of the chemist's skilful play in the laboratory with test tubes, beakers, flasks, filters, condensers, etc. The efficiency of the complete process is the product of the individual efficiencies with which these unit operations are carried out.

A close analysis of the different factors upon which the efficiency of each unit operation depends provides the data from which the necessary plant units can be designed for carrying out each operation, and, ultimately therefore, the complete process, with a maximum of efficiency. In this way, a study of the individual unit operations provides the means for the effective control of the complete process, however complicated the process may be or whatever the reaction materials that may be used in it.

The various unit operations which, when selected and arranged

in their proper sequence, make up such a wide variety of processes may be classified as follows :

(*a*) Physical operations such as crushing and grinding, dissolving, filtering and settling, evaporating, drying, distilling, crystallising, etc.

(*b*) Chemical operations such as oxidation, combustion, etc., reduction, hydrogenation, nitration, chlorination, etc., electrolysis, double decomposition, catalysis, pyrolysis, etc.

We may regard these operations as constituting the warp threads, so to speak, of the chemical engineering fabric.

When we analyse the design of the plant required to carry out one of these operations, we find that it depends upon a knowledge of the physics of fluid flow, of heat transmission and mass transfer, as well as of the chemistry of heterogeneous equilibria, mass action, surface energy (colloidal behaviour), electrochemistry, etc. A sound knowledge is also necessary of the mechanical and chemical properties of the available constructional materials, of the engineering methods employed in the construction and erection of the plant and supporting structures, and of the general principles of plant arrangement and control. Further, it is necessary to be familiar with the economic principles that are involved in the financing of industry, in the costing of the production processes, in the sale of the products and in the allocation of the resulting revenue. We may regard all these different requirements as constituting the weft threads of the chemical engineering fabric.

Probably the three most important sets of principles with which the chemical engineer has to deal are those which are involved in the transmission of heat, in the flow of fluids and in the transfer of material by diffusion from one phase to another. The transmission of heat to or from a reaction mass is a determining factor in a very large number of chemical engineering operations—*e.g.* heating or cooling, evaporation, distillation, crystallisation. The rate at which heat can pass through the heating or cooling surface not only determines the capacity of a given plant but may also decide the extent to which a given reaction can be controlled. It is found that every body of fluid is surrounded by a stagnant boundary film, through which heat can pass only by the relatively slow process of conduction, whereas in the free-moving body of the fluid it is conveyed from one point to another by convection at a rate which depends upon the mobility of the fluid and the temperature gradient. The existence of this highly resistant boundary layer is of the greatest significance to the plant designer. If he wants to check the flow of heat from a hot vessel, he does all he

can to multiply and stabilise these stagnant fluid films, insulating the hot vessel with a medium possessing a finely cellular construction. If he wishes to promote heat flow across a heating or cooling surface, so as to reduce the dimensions and, therefore, the cost of the plant that is necessary for a certain capacity, he reduces the thickness of the film and disturbs it as much as possible by causing the fluid to flow over the heating, or cooling, surface at as high a velocity as he can afford to maintain.

Two notable examples of the successful adoption of this principle are the forced-circulation evaporator, in which the liquor to be evaporated is pumped at a high velocity through steam-heated tubes, and the pipe still that is used in the refining of petroleum, in which the highly viscous crude oil is forced first through banks of pipes which are exposed to the intense radiant heat from an oil flame, and afterwards through more pipes which are heated externally by the hot gases from the flame. In each of these pieces of equipment, the forced circulation of the heated liquid greatly increases the capacity of the plant.

When a fluid flows through a pipe or reaction vessel, a considerable amount of its energy of motion is dissipated (*a*) in overcoming the tangential drag of the surfaces which enclose it and (*b*) in setting up eddies and internal disturbances in response to the sudden changes of direction that result from the irregularity of its path. There is therefore a close connection between the power consumed in pumping a given fluid through a pipe line or reaction vessel and the form and dimensions which are given to these vessels by the designer. Considerable sums of money may be saved by the suitable streamlining of the path of the flow, just as in the closely related problems that arise in the design of aeroplanes and racing motor-cars.

On the other hand, a vigorous agitation or disturbance of the fluid may sometimes be sufficiently advantageous—as, for example, in promoting more rapid heat transmission—to justify the greater power consumption.

The concept of a stagnant boundary film also plays an important part in the design of mixers, emulsifiers, scrubbing towers, gas washers and absorbers and fractionating columns, in which two fluids are brought into contact with the object of promoting the passage of some constituent from one to the other. The diffusion of this mobile constituent across the interfacial boundary is resisted by two stagnant fluid films. Depending upon the relative solubility of the diffusing constituent in the two fluids, the resistance of either the one or the other fluid film may control the rate of transfer of the material, or both film resistances may play an essential part.

For a given case, it is possible to determine the relative resistance of these films and, by designing the plant so as to impose a high velocity upon the fluid which offers the greater film resistance, the rate of mass transfer, and, therefore, the capacity of the plant, can be greatly increased.

In many other ways, the analysis of the mechanism by which, for example, vapour leaves a hot liquid or a filtrate passes through a filter cake and cloth, or suspended particles in a liquid cling to rising air bubbles, or condensing vapours flow over surfaces which they do not wet, it is possible to derive valuable data and formulæ which enable the designer to produce a scientifically planned and, therefore, highly efficient piece of plant.

Similarly, the analysis of the conditions under which a plant is operated, whether it be examined from the standpoint of the convenience of control or the prevention of avoidable corrosion or depreciation of the plant units or the reduction of working costs, provides information which is of immediate value to the plant under consideration and can be used effectively to improve the design and arrangement of new plants.

Chemical Engineering a Synthesis

The relations which exist between a chemical process and the plant in which it is carried out are far more intimate and important than those which exist between a man and the clothes he wears. Most men—except, possibly, the over-fastidious—can live and move and have their being with but little reduction of activity or quality of output, whether they work in ready-made clothes or in a tailor-made suit from Savile Row. A chemical process, on the other hand, can only work with the highest efficiency if it is clothed in a tailor-made plant designed with the greatest skill to facilitate the maintenance at every point of the process, both in time and space, of precisely the right physical and chemical conditions.

The ultimate object of the chemical engineer's analysis is to find out how to design such a plant that will be perfectly adapted to the needs of the process. He is, however, no unrestrained idealist. He knows that the process must in the last resort show a financial profit. His carefully designed plant may increase the output and improve the uniformity of the product, it may cut down heat losses and labour costs, it may reduce the wastage of materials and bring the process nearer to the desired goal of a profit-earning proposition, but, to do this, he may have to sacrifice a high yield or reduce the quality of the product to a level which the market will just tolerate.

The designer of any kind of plant unit is necessarily restricted in his choice of materials to those which are commercially available, and in the construction of the plant to those methods of fabrication which are suited to these materials and are in common use. In this respect, the chemical engineer has benefited greatly in recent years by the great improvement that has been made in the quality and range of materials at his disposal—to mention only aluminium, Monel metal and the various heat-resisting and corrosion-resisting alloy steels, as well as the great advances that have been made in the properties of rubber, chemical stoneware, refractories and in the introduction of special cements, synthetic resins and plastics. A corresponding development in the methods of plant fabrication —for example, fusion welding and the casting and pressing and shaping of large plant sections and the control of the ultimate properties of the metal by suitable heat treatment—have increased enormously the range and flexibility of design that is possible. Instead of a limited range of cast-iron and stoneware vessels of which the design bore no relation to the purpose for which they were to be used, it is now possible to clothe a chemical process in a well-fitting plant, constructed as far as possible of resistant materials and arranged in the most convenient way for controlled operation.

The old-time process was frequently hampered by a distorted arrangement of the various plant units. Sometimes, they had to be fitted into an existing building, or a number of different driving pulleys had to be driven from a single line of shafting which in its turn was driven by a steam engine or a large electric motor. No such restrictions are imposed upon the design or arrangement of a modern installation. The arrangement of the complete process is treated primarily as a problem in the handling and conveying of a given reaction material through a number of unit plants in which it is to be subjected to various kinds of treatment. The positions are determined at which the material is to be stored, is to enter each unit plant, is to pause, if necessary, between successive unit operations, and finally is to pass out of the plant as a finished product to be stored or packed and despatched. Provision is made for the introduction *en route* of reagents or intermediate materials and for the removal of by-products. Each unit plant is designed and fitted into the complete process, so that not only will it perform its appointed task efficiently but will also facilitate the passage of the material through the process. The development of mechanical handling and conveying equipment and the use, wherever possible, of individual motor drives has contributed a great deal to make this greatly increased flexibility and freedom of arrangement possible.

Wherever practicable, the process is arranged so as to be capable of continuous operation, particularly when it is on a large scale —*e.g.* cement or sulphuric acid. Such a process, once it has been tuned up, can be operated automatically with a great saving in operating and maintenance cost and with a corresponding improvement in the uniformity and quality of the product.

The control of any chemical operation is a vitally important matter to which careful attention should be given by the designer. All too often, thermometers, gauges, control valves are distributed all over the plant, frequently in dark and difficultly accessible places. This involves much wasteful expenditure of human effort and results in a considerable loss of efficiency All control instruments and fittings are, therefore, grouped as far as possible in a conveniently central position from which the whole series of operations can be controlled by the operator with a minimum of physical effort.

Adequate facilities are provided for the withdrawal of any piece of plant from the process for repair or replacement.

Finally, when all is complete and the plant has been designed and arranged so that each part may function efficiently and exhibit a maximum of convenience and accessibility, a suitable building is erected to protect the plant and the workers from the weather.

Conclusion: The Training of the Chemical Engineer

Industry to-day is becoming increasingly dependent upon chemical processes for the provision of new materials. These processes are multiplying rapidly in all directions. A chemical process is of such a character that, unless it be operated with every refinement that science can provide, the quality of its product will be irregular and the cost of production greatly increased. It is necessary, therefore, for these industries, in particular, to be staffed and directed by scientific men who have been trained not only to be scientifically efficient, but also to be industrially effective. The chemical engineer is a prototype of the scientifically trained industrialist who will control the scientifically organised industry of the future. What sort of man should he be? How should he be trained?

There are those who say, and with a considerable amount of truth, that a chemical engineer is born rather than made. In so far as he should be equipped with certain personal qualities such as a firm will, a clear mind, a capacity for forming rapid yet sound judgments upon men and events, a talent for direction and leadership, a capacity for really hard work and an incurable optimism, the observation is sound. But everyone who has to do with the training of youth knows how the development of latent powers both

of intellect and character depends very largely upon right training and opportunity. As far as possible, however, students who wish to become chemical engineers should be carefully selected in the first instance, not only for their intelligence but also for their personal qualities.

It is difficult for a man to get a university training in this country that will equip him for the profession of chemical engineering. He can get a training in pure science and learn how various substances behave under ideal conditions. But he must find out for himself how to translate the ideal into the real when he has exchanged the laboratory for the factory. This is a fundamental mistake. The universities were established in the first instance for the purpose of training students for the professions—law, medicine and the Church. The training they provided was definitely vocational, combining theory with application. The tendency in some universities to-day to look askance at vocational courses is, therefore, entirely without justification. Chemical engineering, as I see it, is not simply a particular form of applied science ; it is an attitude towards manufacturing industry which, being based upon a systematic knowledge of the fundamental realities of which industry is the expression, sees it clearly because it sees it whole. Industry in a scientific world needs scientifically trained men to plan and control its various processes. It needs such men, also, to direct its policy and development with a sensitive finger upon the pulse of scientific progress. To these men will fall the task of directing industry and society through the economic and social changes which, even now, are resulting from the widespread impact of science upon our industrial and social system.

The training of these men is essentially a task for the universities. It must be based upon a systematic treatment of the fundamental sciences and of the way in which they can be applied constructively to the solution of industrial problems. It must be infused with the spirit of research and progress. It must enable the student to cultivate a frank outlook and an unbiassed judgment. It should arouse in him a sense of enterprise and vocation.

The present method of training chemical engineers which obtains in the University of London is to supplement an Honours Degree course in chemistry or engineering by a post-graduate course in chemical engineering. This post-graduate course consists of a systematic training in the principles and practice of such subjects as the flow of fluids, the transmission of heat, the mechanical and chemical properties of different materials of construction, the principles of mechanical engineering, the production and distribution of

energy in a works, and the design and operation of the different unit types of chemical plant. The theoretical treatment is supplemented by good problem classes and reinforced by practical courses in the machine shop, drawing office and industrial laboratory. During his training, the student pays frequent visits to selected works to study plant design and operation on the spot, and is encouraged to obtain vacation employment in a works. Thus, he acquires a first-hand knowledge of works organisation and atmosphere. The complete course provides him with a well founded, systematic training, both in the theory and practice of his profession. Such a training in the theory and practice of chemical engineering produces a type of man who can go into industry and not only develop his full output of efficient service without undue loss of time, but, throughout his career, be better able to operate existing processes with a maximum of efficiency as well as plan the profitable development of new ones.

There is already a growing demand for men who have been trained in this way. Those who have already entered industry are giving a splendid account of themselves. There is every prospect that the future of industry in this country will be in safe and capable hands when it is entrusted to those who, having been trained in the first instance as chemical engineers, have learned subsequently in the school of experience how to apply the principles of science effectively to the organisation and direction of industry.

THE HYPERFINE STRUCTURE OF SPECTRAL LINES

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Spectroscopic research, which has been so intensively pursued during the last thirty years or so, and which has provided such a wealth of information concerning the structure and mechanics of the atom, has until recently been mainly concentrated on the compilation of wavelength data, expressing the positions of spectral lines, and on the discovery and interpretation of regularities in these data. It is in this way that much of our knowledge of the arrangement of the electrons within the atom has been gained, and in some respects this knowledge may now be said to be nearly complete. The majority of the more important atomic energy levels have been located, and only a few complex atomic spectra remain to be analysed. Existing data will be extended as observations in the less accessible regions of the spectrum, the far ultra-violet and infra-red, are secured, but so far as one can see the work to be done in this field is in the nature of filling in gaps by known and well-tried methods. There is little prospect, dangerous though it is to prophesy, of the emergence of anything essentially new from further study of the positions of spectrum lines.

The fear of unemployment does not as yet begin to oppress the experimental spectroscopist, however. Having more or less worked out the vein which we may designate as the macro-structure of spectra, he is finding plenty to occupy and interest him in the study of their micro-structure. It is not a new study, for so long ago as 1887 Michelson, in his search for a suitable standard of wavelength, found evidence of fine structure in a number of lines previously regarded as single. In fact, the only one of the lines he examined which appeared to be perfectly free from structure was the Cadmium red line at 6,438 Å which was subsequently adopted as the primary standard, and serves as such to this day.

His interferometer, however, was not capable of directly resolving the structure, that is to say of separating the components from one another. He inferred the positions and intensities of the components by harmonic analysis of the curves obtained by plotting the visibility of the fringes against the path difference of the beams. His results were surprisingly accurate, but the difficulty of the method was such as to prevent its general adoption, and little further work in this field was attempted until after the advent of the multiple beam type of interferometer, which is capable of direct resolution of fine structure.

The Experimental Problem

There are two main requirements which must be fulfilled in experimental work on fine structure. In the first place the lines to be examined should be as narrow as possible, so that the components overlap each other as little as possible. In the second place a spectrograph of sufficient resolving power must be available, in order to obtain separated images of the components. In a few cases a large grating, or even a prism instrument, is adequate for the purpose, but some type of interferometer is usually necessary. In order to meet the former requirement several special techniques have been developed with the object of reducing the various causes of line broadening to a minimum, whilst maintaining a sufficient intensity of the radiation. The main factors which tend to broaden spectral lines are temperature, which gives rise to Doppler effects associated with the atomic velocities, pressure and electric fields. Lines subject to absorption present special additional difficulties, since not only do they tend to be broadened in consequence of successive absorption and re-emission, but the absorption may give rise to apparent doubling which is difficult to distinguish from genuine fine structure.

The problem therefore is to obtain a source of reasonable luminosity in which the gas is comparatively cool, of low density and subject to a negligible electric field. None of the usual spectroscopic sources such as flames, arcs, sparks and the ordinary type of vacuum discharge tube is capable of satisfying all of these requirements. For the solution of the problem, in the form of the hollow cathode discharge tube, we are indebted in the first instance to Paschen. He found that it was possible to obtain an intensely luminous discharge inside a tubular cathode. The field is very small in this region, and the cathode may be cooled by liquid air if desired provided that some gas is present in addition to the metal or compound under investigation. Helium or argon at a pressure

of a few millimetres of mercury is commonly employed, and continuously circulated through the apparatus, suitable traps for impurities being inserted at some point in the circuit. Owing to the high rate of dissipation of energy within the cathode the consumption of liquid air is rather excessive, but frequently water cooling is found to be almost as good. In this way it is possible to obtain brilliant spectra of substances having quite low vapour pressures, and the lines are sharp enough to permit the use of very high resolving power. Another source which has proved its value for fine structure work is the high frequency discharge. In this method an oscillatory potential is generated by a valve circuit working on a wavelength of 10 to 100 metres or so, and is applied to electrodes wrapped round the tube externally. If the pressure is sufficiently low a luminous discharge is produced which practically fills the tube, and which gives very sharp spectrum lines. The method is extremely simple and convenient once the generating circuit has been fitted up; the fact that it has been comparatively little used is probably due to the wider range of application of the hollow cathode type of tube, and the ease with which high intensity of illumination may be obtained from it. In the high-frequency method also the presence of rare gas is often very advantageous, especially when resonance lines are being examined. In pure vapour these would be extremely broad, but they can be obtained quite sharp by the addition of a relatively large proportion of a gas having a high ionisation potential.

Turning now to the question of the most suitable spectroscopic apparatus for these investigations, we find a variety of instruments to be available. Large diffraction gratings, Fabry-Perot interferometers, Lummer-Gehrcke plates and Michelson echelon gratings have all been used, and each has advantages and limitations peculiar to itself. The diffraction grating, for example, has a large range in wavelength, but a resolving power which seldom reaches a quarter of a million. Although this would usually be ample for other spectroscopic purposes, it is seldom adequate for fine structure work and may be considerably exceeded in the case of the other instruments mentioned. In the case of a few elements which show coarse and simple fine structure, gratings have been successfully employed, but the interferometer must be regarded as the standard apparatus for this class of work. The various types mentioned are based on the same fundamental principle, the interference of a number of beams each having the same large path difference relative to its neighbour, and the resolving power is given by the product of the number of beams and the path difference expressed

in wavelengths.[1] It is essential that the path differences between successive beams shall be identical to within a small fraction of a wavelength, a requirement which taxes the skill of the instrument maker to the utmost. In one case, that of the reflection echelon, the technical difficulties of manufacture have only been overcome quite recently, although it is now thirty-five years since Michelson first proposed the construction of such an instrument.

All of these interferometers have one drawback in common; they give rise to successive orders of spectra which lie so close together that only a very small region can be examined at one time, and an auxiliary spectrograph is therefore required to isolate such a region. Some of them, notably the Lummer plate and transmission echelon, are occasionally found to give false images simulating fine structure components. These may be detected by using two interferometers in series with their dispersions perpendicular, but this involves considerable loss of light and complicates the experimental arrangements. Such "ghosts" cannot occur with the Fabry-Perot instrument, and it has the further great advantage over all other types that the dispersion and resolving power may be varied within wide limits by altering the separation of the plates and the thickness of their metallic coating. Increase of plate separation gives higher resolving power, but at the same time the fringes are more closely spaced and the overlapping of adjacent orders becomes more troublesome. There is also a practical limit to the thickness of metallic coating, on account of the loss of light attending the use of thick films. For strong lines heavily coated plates, having a high reflecting power, may be employed, but weaker lines necessitate comparatively transparent films, with a consequent reduction in resolving power. The composition of the film is another point requiring consideration, since the reflecting powers of metals vary widely with wavelength. Thus for example, whereas silver is quite satisfactory in the visible region, and particularly so at the less refrangible end, it is practically useless in the ultra-violet. In this region aluminium, silicon and magnesium have been employed, but none of these has such a high reflecting power as that of silver in the red. In all these cases a special technique for coating the plates is necessary. The ordinary chemical methods are incapable of giving a film of the requisite uniformity and reflecting power, and until recently the

[1] Although the number of beams is theoretically infinite for the Fabry-Perot and Lummer plate, their intensities fall off regularly and it is therefore possible to define an effective number of beams, which renders the above statement generally applicable.

method of cathodic sputtering was used. This has now given way to a process in which the metal is evaporated from a heated tungsten filament in a high vacuum. The resulting film is not only highly reflecting but remarkably durable. Nevertheless, the best results are obtainable only with freshly coated plates, and an evaporation apparatus is therefore coming to be regarded as a very desirable adjunct to a Fabry-Perot interferometer which is employed in fine-structure work The reflection echelon, although only a very few have as yet been made, promises valuable assistance in this field. Its resolving power is high, it wastes very little light, and it is practically unaffected by mechanical vibrations or fluctuations of temperature and pressure. Moreover, it is almost as effective in the extreme ultra-violet region, between 2,000 and 2,500 Å, say, as at higher wavelengths, whilst below 1,850 Å, where quartz absorbs strongly, it is the only instrument available. No interferometric work has yet been done in the latter region.

It will be gathered from the above that the investigation of the fine structure of spectral lines calls for spectroscopic equipment of a varied nature and of the highest quality, together with much skill and experience on the part of the experimenter, if the apparatus is to be used to the best advantage Even so, many of the results obtained may be difficult or indeed impossible to interpret unambiguously. It is therefore hardly surprising that the development of this branch of spectroscopy has been marked by a certain amount of disagreement and controversy between different workers. Improvements in technique, increased experience and theoretical advances are combining to resolve such differences, and we are now in possession of a body of knowledge, which whilst admittedly far from complete, is yet sufficiently extensive and significant to warrant its presentation, in summary form, to the general scientific reader.

Magnetic Hyperfine Structure

The term hyperfine structure is not applied indiscriminately to all cases of complexity in line structure but is used with a special significance. It implies that the structure cannot be interpreted in terms of the three quantum numbers associated with multiplet structure, namely L, S, and J, which define the orbital, spin and total angular momenta respectively. That is to say, close multiplet structure and fortuitous proximity of lines are excluded. For example, the lines of the orthohelium spectrum, although separable into closely spaced components, show no hyperfine structure ; again, the lines of ionised lithium show both close multiplet structure and

genuine hyperfine structure of the same order of magnitude. Incidentally, this clearly shows that hyperfine structure is due to the nucleus, since the electron configurations are identical for the two atoms. Further, hyperfine structure is of two distinct types, one of which is referable to nuclear magnetism and the other to nuclear mass. The former arises from one and the same atom in different energy states, the latter from two or more distinct isotopic atoms. Consequently the component levels may combine with one another in the former case, but they cannot do so in the latter. Both types of structure often occur together, but it is convenient to consider them separately in the first instance and the present section will therefore deal with the magnetic type.

Since magnetic hyperfine structure is closely related to ordinary multiplet structure a brief summary of the essential features of the latter may be introduced at this stage in order to render the subsequent account of the former intelligible to those who are not conversant with modern spectroscopic theory. In the simplest type of spectrum, in which the energy levels and consequently the lines are all single, these levels may be classified into families or groups which may each be designated by an integral quantum number L, expressing the angular momentum (in quantum units $h/2\pi$) of the electronic configuration associated with the group in question. Only the lowest values of L, 0,1,2, etc., need be taken into consideration in practice. All the lines of the spectrum can then be predicted correctly by forming the energy differences between every pair of levels for which L differs by unity. In current spectroscopic terminology, we say that all possible combinations can occur, subject to the selection rule $\Delta L = \pm 1$. Such singlet spectra are rare, in fact no atom gives only a singlet spectrum ; but many, such as He and Ca, give both singlet and triplet systems which are quite independent of one another, although they always occur in company.

In order to account for such triplet systems or for multiplets in general, a further quantum number, J, must be introduced, to distinguish the sub-levels which take the place of the single levels in the simplest case. It is then possible to label successive sub-levels in each set with J values successively increasing by unity, the absolute values being so chosen that when the sub-levels of one set (for which $L = L_1$, say) combine with those of another set (for which $L = L_1 \pm 1$) the lines which are experimentally observed correspond to changes in J of 0 or $\pm$ 1 only. That is to say, all the combinations which actually occur in multiplet spectra obey the two selection rules $\Delta L = \pm 1$, $\Delta J = 0, \pm 1$. There is only

one assignment of J values which will account for the presence of all the observed lines, and for the absence of all other combinations, and it remains to indicate how this assignment is arrived at. For this purpose only one essentially new, *ad hoc*, assumption need be made, namely that the electron possesses, in addition to its orbital angular momentum $l.h/2\pi$ an intrinsic "spin" angular momentum $\frac{1}{2}.h/2\pi$. Each of these momenta will have a magnetic moment associated with it, and the magnetic momenta will interact with one another, giving rise to various stable configurations. In the majority of spectra the interactions may be described as follows. Firstly, the individual orbital momenta (the *l*s) combine to give a resultant L. Secondly, the individual spin momenta (each $\frac{1}{2}$) combine to give a resultant S. Finally, L and S combine to give a resultant or total angular momentum J. All these combinations take place in accordance with quantum principles, whereby two atomic vectors, P,Q (P $>$ Q) can only give resultants P + Q, P + Q − 1, and so on down to P − Q.

As the simplest possible example of multiplet structure we may take the sodium D lines. The sodium atom has one outer electron, so that S = $\frac{1}{2}$. In the normal state of the atom L =0, and thus J = $\frac{1}{2}$. In the state of lowest excitation energy L = 1, giving two possible values of J, 3/2 and 1/2. Two lines are therefore emitted or absorbed when transitions take place from one of these states to the other; from one (D_1) the two J values are 1/2 and 1/2 and for the other (D_2) they are 3/2 and 1/2. If we take next an atom such as Ca having two outer electrons, we find two systems, one singlet and the other triplet. In the former case the spins are opposing or anti-parallel, giving S = 0 and therefore J = L, *i.e.* all the levels are single. In the latter the spins are parallel, S therefore = 1, and in general three J values occur, namely L + 1, L and L − 1. As an example of the multiplet structure which results we may consider the group of six Ca lines between 4,425 and 4,457 Å. Here the L values are 1 and 2, giving the J values 0,1,2 and 1,2,3

Which combinations are possible can be easily seen by writing the J values as below, with diagonal lines joining all pairs for which Δ J = 0 or $\pm$ 1

L = 1, J = 0

L = 2, J = 1 2 3

The fact that the two triple levels give only six lines instead of nine is thus very concisely expressed by the statement of the selection rule J = 0, $\pm$ 1. If this were an isolated case the procedure

outlined above might justly be regarded as somewhat arbitrary, even empirical perhaps; but it acquires unquestionable physical status and significance when it is found to be capable of accounting with equal success for all the essential features of every multiplet spectrum.

We are now in a position to resume the consideration of magnetic hyperfine structure. Since the three quantum numbers already used, L, S, and J, are fully employed, so to speak, in accounting for multiplet structure, a fourth one must be introduced and there is plenty of evidence which leads us to connect this with the nucleus of the atom. We therefore attribute to the nucleus an angular momentum $Ih/2\pi$, with which is associated a magnetic moment, and which is therefore capable of interacting with J so as to give a resultant F. This may take the values I + J, I + J − 1 and so on down to I − J or J − I, whichever is positive, so that if I > J there will be 2J + 1 levels and if J > I there will be 2I + 1 levels. This corresponds exactly with the coupling of L and S to give a resultant J. Since the energy of coupling between I and J is relatively small the resulting F sub-levels lie close together. Further, combinations occur between those sub-levels for which F changes by 0 or ± 1, the corresponding rule governing the formation of multiplets, Δ J = 0 or ± 1, being satisfied at the same time. The example given below may help to make this clear. It refers to the line 3,596 Å of the bismuth arc spectrum, which results from the combination of two levels having J = ½ and 1½. Since I = 4½ for the Bi nucleus the values of F are 5,4 and 6,5,4,3 respectively, giving six possible transitions, 5 → 6,5, or 4, and 4 → 5,4, or 3. These, together with the intensities of the resulting lines, are indicated in Fig. 1 (p. 428). The structure in this example is comparatively simple in spite of the high I value, because of the small J values involved. Further, the spacing of the sub-levels is considerably different in the two cases and relatively wide in each. If only one of these three conditions should not be fulfilled the structure may become very confused and difficult to interpret. If the overlapping of components is not too pronounced it may still be possible to interpret the pattern with the aid of a graphical method due to Fisher and Goudsmit, but before explaining this it is necessary to say a word about level intervals and line intensities.

The overall separation or spread of the hyperfine levels is proportional to the energy of coupling of the nucleus and the optical electrons, that is to say those composing an outer unclosed shell. This coupling energy depends on the magnetic moment of the nucleus and the electronic configuration, and may be either positive

or negative. To be more explicit, the energy may increase with F or the reverse, and the resulting level structure is respectively termed regular or inverted. Both types may occur in the same spectrum, but the intervals between successive levels are usually in a definite ratio to one another, whatever the absolute separations and whether the structure is regular or inverted. The ratio is approximately that of the upper of the two F numbers associated with each interval. This is illustrated in Fig. 1 by the agreement of the numbers in the right-hand column. The rule is the same as Landé's interval rule for multiplet levels, but whereas in the latter case exceptions are quite common they are comparatively rare in

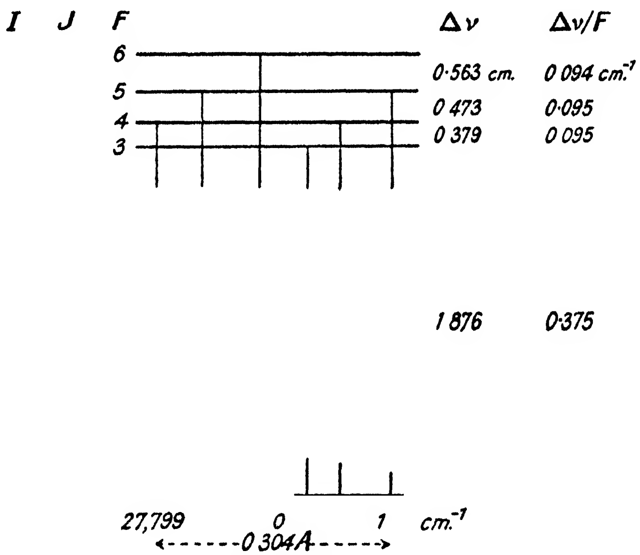

Fig. 1.—Hyperfine structure of BiI, 3,596 Å.

the former, and such as occur are traceable to the perturbing influence of other electron terms in the same neighbourhood. The deepest terms usually show the widest separations and the latter increase with each successive stage of ionisation. They also show a well-marked tendency to increase with atomic weight.

With regard to the relative intensities of the line components it is only necessary to say that they may be calculated from expressions involving J, I, and F, derived by means of the wave mechanics. Here again the analogy with the case of multiplet intensities is complete, in fact the same expressions may be used, *mutatis mutandis*.

We may now return to the Fisher-Goudsmit method of interpreting hyperfine structure. It is applicable to cases in which the

structure of one level (say the lower) is known, whilst for the other only the F values are known, or suspected, the intervals being unknown. The interval rule is assumed to hold, and the actual intervals may therefore be written A′F, where F applies to the upper level of the pair and A′ is the "interval factor" of the upper level. Its value is unknown, and it may be positive or negative, giving a regular or inverted set of levels respectively. A′ is first taken equal to A″, the interval factor of the lower level, and the resulting structure plotted as in Fig. 2, which illustrates the application of the method to the same line as before, Bi 3,596 Å. Next the structure which would result from $A' = 0$ is plotted on a parallel line below the first. The sextet degenerates in this instance into a doublet having the separation of the lower J level.

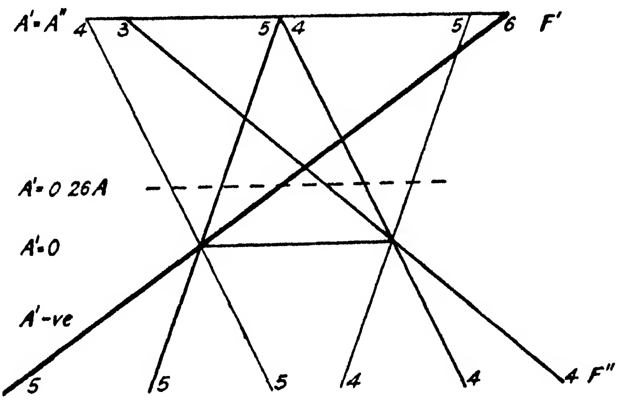

FIG. 2.—Application of Fisher-Goudsmit method to the interpretation of the hyperfine structure of BiI, 3,596 Å

Diagonal lines are now drawn joining the points representing corresponding components, and produced downwards. The breadths of these are made roughly proportional to the calculated intensities. The appearance of the multiplet associated with any particular value of A′/A″ will then be represented by the intersections of the diagonal lines with a horizontal line at the appropriate height above or below the centre line $A' = 0$. The region above the latter corresponds to a regular upper level structure (A′/A″ + *ve*) and that below to an inverted one. Conversely, if the observed multiplet is plotted to the scale of the diagram it should be possible to find a position in which the components will fit the diagonal lines, and if this can be done the interpretation and the actual value of A′ follow immediately. The dotted line in the figure indicates where the fit is obtained, and gives the value of A′/A″ as + 0·26 in this case. The

method is particularly valuable when the structure is complex and the components incompletely resolved.

There is one other characteristic of magnetic hyperfine structure which should be mentioned, namely the Zeeman effect. It will be obvious that serious experimental difficulties may be anticipated in attempting such observations, since the effect of a magnetic field is to resolve a line into a number of close components, and if the original lines are already close together their Zeeman patterns may be inextricably intermingled. This expectation is realised in very many instances, but there are others in which the interpretation of the pattern is quite feasible. For this we are indebted to the so-called Paschen-Back effect, whereby many of the Zeeman components of the original lines fuse into one another, thus considerably simplifying the pattern. As with multiplets, the effect sets in when the magnetic field is sufficiently strong to produce separations comparable with the original ones without field, and since the original hyperfine separations are always quite small the requisite field strength is readily obtainable The cause of the simplification is the breaking down by the applied field of the coupling between I and J and the consequent elimination of F. That is to say, the hyperfine levels no longer exist, and the Zeeman pattern resembles that of a line having the same J values but no hyperfine structure, except that each main Zeeman component is split into $2I + 1$ equally spaced sub-components. If these can be resolved, as was done by Back for Bi, we obtain a very direct and unambiguous value for I. Whilst this method is not generally applicable, for the reasons indicated above, and has been very little used up to the present, it is likely to prove extremely valuable in certain special cases. The Zeeman effect on hyperfine structure components is also intimately connected with the depolarisation of resonance radiation by a magnetic field, and it has been found possible to derive information concerning nuclear moments from observations of the latter phenomenon, in cases where direct observation of structure was impracticable.

Isotopic Hyperfine Structure

The isotope effect in molecular spectra has been the subject of much investigation. It takes the form of displacements of considerable magnitude, often observable using quite small dispersion, which are completely explicable on simple theoretical considerations. The case is very different with atomic spectra. Here the effect is invariably small, and is frequently so confused with hyperfine structure of the magnetic type that it was necessary to establish

the laws governing the latter before any systematic knowledge concerning it could be gained. The results that have emerged are of unexpected complexity and for many of them there is as yet no theoretical explanation. For both these reasons we shall attempt little more than a brief survey of the experimental facts.

The Rydberg constant, as calculated from the Bohr-Sommerfeld theory (and the wave-mechanics gives the same expression) contains a factor $1/\left(1+\frac{m}{M}\right)$ where m and M are the electronic and nuclear masses respectively. Thus if M increases by Δ M the Rydberg constant T is increased by a fraction $\frac{\Delta R}{R}=\frac{m}{M}\cdot\frac{x}{1+x}$, where $x=\Delta M/M$. For example, in order to calculate the displacement of the lines of the heavy hydrogen isotope H^2 relative to the Balmer series lines we must put $m/M=\frac{1}{1840}$ and $x=1$, which gives $\frac{\Delta R}{R}=\frac{1}{3680}=-\frac{\Delta\lambda}{\lambda}$. The displacement of $H^2\alpha$ relative to $H^1\alpha$ ($\lambda=6{,}563$ Å) should thus be $-\frac{6563}{3680}=1.8$ Å towards the violet, in good agreement with observation. Although the Bohr-Sommerfeld theory is strictly applicable to hydrogen-like atoms only, the Rydberg constant appears in the term functions of all series spectra, and we might therefore hope to calculate isotopic displacements in general in the above manner. In point of fact, however, there is no other spectrum in which the isotopic shifts can be so explained. They are usually larger than the "Rydberg displacements," frequently very much larger, and sometimes they are opposite in sign. Thus for the two Hg isotopes of masses 198 and 204 the above formula predicts a displacement of 8×10^{-6} per cent. corresponding to $0{\cdot}003$ cm.$^{-1}$ at 2,536 Å, whereas the observed value is about 0.5 cm.$^{-1}$. Again, in the Tl I and Tl II spectra the displacements are not only unexpectedly large but are of opposite sign. Since we are here dealing with the same nucleus it is quite clear that the displacements must be primarily determined by the electronic configurations, and this is confirmed by a detailed study of the effect in various spectra.

In addition to H, Hg and Tl, isotopic structure has been detected in the spectra of Li, Ne, Mg, Cl, K, Cu, Zn, Br, Cd, Sn, Ba, W and Pb. In the case of Li II the displacements are about four times as great as could be attributed to the mass effect on the Rydberg constant, but since there are only two electrons an approximate solution of the wave equations is possible, and has been found by Hughes

and Eckart to account very satisfactorily for the observed results. Neon too shows comparatively large shifts, which are also explicable, at least in part, but this marks the limit of theoretical achievement at the moment. Of the remaining elements the three heaviest, Hg, Tl and Pb provide the best data, and all show large shifts, some characteristics of which merit attention. As in all other spectroscopic analysis the ultimate aim is to deduce the energy levels from observations of the lines, but with isotopic line structure an unusual difficulty is encountered, on account of the absence of combinations between levels belonging to different isotopes. The nature of the difficulty may best be explained by considering in the first instance what would be the effect of a constant displacement of the levels of one isotope relative to those of another. Since line frequencies represent differences between levels this would evidently give rise to no line displacements at all, and such an isotope effect would therefore be quite unrecognisable spectroscopically. Any other type of level displacement will be reflected in the lines, but there must always remain the possibility, however remote it may be in the light of other considerations, that a constant level displacement may be present in addition to any other type which has been detected

The next simplest type of effect would be if the term values of one isotope were in a constant ratio to those of another, as in the "Rydberg displacement." This would give rise to structures of widths proportional to the frequencies of the lines, but this as we have seen, is far from being the case. Nevertheless, there is one respect in which the observed displacements do conform to the Rydberg type, namely that they tend towards zero as the energy levels approach the ionisation value. This is to be expected, since the less firmly bound the electron the less will be the influence of the nuclear mass. It is a fortunate circumstance, because it provides a starting point for the derivation of the isotopic level splitting from the observed line structures. In practice, one first investigates a line due to combination between a high and a low-lying level, in the expectation that the structure will be due principally to splitting of the latter. The assumption is then checked by examining other lines involving each of the levels in question, and if it is found to be justified the structure of the low level is established. When once this is known the structure of other levels which combine with it may be deduced, and so on with as many other levels as may be practicable. It should be understood that the above description relates to the simplest possible case, that in which none of the isotopes shows magnetic hyperfine structure. If, as usually

happens, some of them do, the same procedure will apply, theoretically at least, to the centres of gravity of each group of components. But in practice the difficulties of interpretation may be very great, calling for consideration of every scrap of evidence, such as intensities, intervals and Zeeman effect. It is occasionally possible to compare the spectra of samples of different isotopic constitution (e g. Pb from various sources) and the problem of identifying the isotopic components of the fine structure is thereby much simplified.

The results for Hg, Tl and Pb, although numerous and inter-

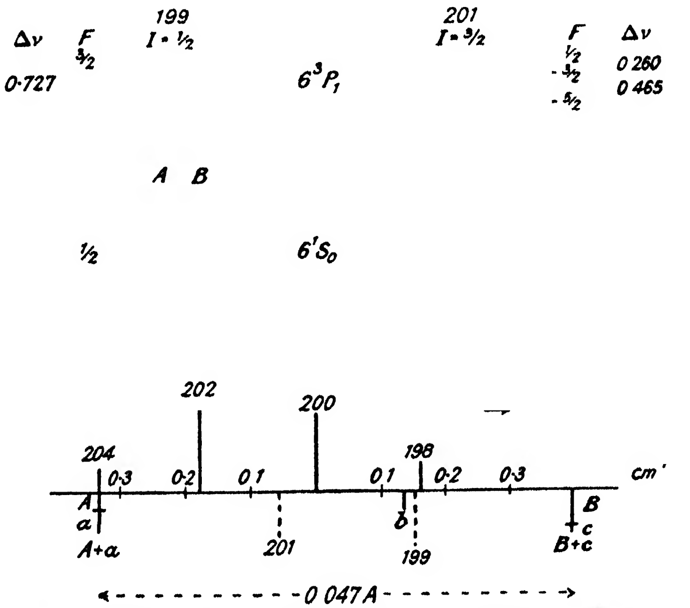

FIG. 3.—Level diagrams and hyperfine structure of HgI 2,536 Å, $6^3P_1 \rightarrow 6^1S_0$.

Components due to even isotopes plotted above, and odd below, line Centres of gravity of latter components shown dotted

esting, do not lend themselves to systematic classification, but their chief characteristics may be summarised as follows :—

(1) In one sequence the displacements decrease with increasing principal quantum number.

(2) They differ widely in different sequences for terms of similar energy values, and do not depend primarily on the depth of the term.

(3) The levels occur in order of atomic weights. The spacing is uniform for a succession of even atomic weights (e g. Hg 198, 200, 202, 204) but the levels of the odd isotopes are slightly displaced from the corresponding positions.

(4) The deepest isotopic level may be that of the heaviest atom, or vice versa, but in any case it is the same for all the terms of one spectrum.

(5) The isotopic separations tend to be greater for the ionised than for the neutral atom, and are not necessarily of the same sign (*e.g.* Tl changes sign, but Hg and Pb not).

An example of isotopic structure is shown diagrammatically in Fig. 3, which represents Schuler and Keyston's interpretation of the hyperfine structure of the well-known Hg resonance line 2,536 Å. The level diagrams for the two odd isotopes, which have different I values, are also given. The asymmetrical positions of the centres of gravity of the 199 and 201 components will be noted. Owing to fortuitous coincidences of several components the interpretation of the structure presented much difficulty, and was only achieved as the result of an extensive and detailed study of a number of other lines in the spectrum.

Moments of Atomic Nuclei

In the event of a successful analysis of hyperfine structure it is possible to determine both the mechanical and magnetic moments of the nucleus. The former may sometimes be deduced from the number of components, but investigation of interval ratios, intensities or Zeeman effect may be necessary in addition. The latter is much more difficult to evaluate, and most of the present results must be regarded as somewhat provisional in character, since they depend on theoretical considerations the validity of which is by no means securely established.

The results available at the beginning of November 1933 are collected in the Table. The mechanical moment (I) is expressed in terms of the usual angular momentum unit, $h/2\pi$, and the magnetic moment (μ) in terms of the proton magneton $eh/4\pi Mc$, e and M being the charge and mass of the proton. In addition to the I values from hyperfine structure work those derived from band spectrum measurements are also included in the table. The rotation branches of a molecule consisting of two identically similar atoms show an intensity alternation from line to line of magnitude $I/(I+1)$, and a value for I may therefore be obtained from intensity measurements on such bands. The method has some rather serious limitations, however. In the first place it is essentially statistical in nature; that is to say, if several values of I existed simultaneously it would not disclose the fact, but would give a weighted mean value. Since the hyperfine structure evidence consistently indicates a unique I for each nucleus this objection probably has

no practical significance. But the method is limited to symmetrical diatomic molecules, and not very many atoms form such molecules, or if they do, their band spectra may not be of a suitable type. For example, the rotation structure may be too close for resolution, or even non-existent. Finally, it is frequently difficult to measure the intensities with the necessary accuracy, especially if I is rather large. Thus to distinguish with certainty between $I = 7/2$ and $I = 9/2$, corresponding to intensity ratios of $7:9$ and $9:11$, requires an accuracy of something like 2 per cent., which is very high for intensity determinations. However, it is satisfactory that in the four cases where I values from both sources are available, they are in agreement. The band spectrum method is particularly precise and trustworthy when $I = 0$, for then alternate lines are completely suppressed, and no intensity measurements are necessary to establish the result. On the other hand, absence of observable hyperfine structure does not establish that $I = 0$, since it might alternatively be due to a small magnetic moment of the nucleus or to a weak interaction with the outer electron shell. Conversely, even though I may be zero it may not necessarily follow that the nuclear magnetic moment is zero also, and on this point much more extensive observations than at present exist would be of interest.

With these facts in mind we may now proceed to consider some of the more significant features of the results presented in the table on the following page.

With two exceptions, H^2 and N, the table includes only nuclei of odd mass number, since we have good reason to believe that even mass number is associated with zero mechanical moment. In no case has any hyperfine structure been found when the nuclear mass is even, and although, as already explained, this is not conclusive evidence for $I = 0$, the only four even nuclei which have proved amenable to the band spectrum method, namely He^4, C^{12}, O^{16} and S^{32}, all have $I = 0$ quite definitely. The conclusion is very natural, and is generally accepted at the present time, that only odd nuclei can have a mechanical moment. We are almost justified in fact in going farther than this, and concluding that they always do have a moment, and that this is always an odd multiple of $\frac{1}{2}$, since all the experimental evidence supports this view. Here again the band spectrum method supplements the hyperfine structure data in a most fortunate way, since it definitely establishes the existence of nuclear moments for at least three nuclei (P^{31}, Cl^{35}, K^{39}) which could not be detected by the latter method, the structure being presumably too close.

The two exceptions to the rule that even nuclei have $I = 0$

Moments of Atomic Nuclei

Atomic No.	Element	Mass No	I	Remarks
1	H	1	1/2*	
		2	1*	
3	Li	7	3/2, 3/2*	$\mu = 3{\cdot}3$
4	Be	9	1/2?	
7	N	14	1*	$\mu < 0{\cdot}2$.
9	F	19	1/2, 1/2*	
11	Na	23	3/2, 3/2*	$\mu = 2{\cdot}6$ I value confirmed by Stern-Gerlach method.
13	Al	27	1/2	I not quite certain, but small
15	P	31	1/2*	μ probably small.
17	Cl	35	5/2*	" " "
19	K	39	> 1/2*	" " "
23	V	51	> 5/2	" " "
25	Mn	55	5/2	
27	Co	59	7/2?	5/2 or 9/2 not excluded.
29	Cu	63	3/2	
		65	3/2	
30	Zn	67	3/2	
31	Ga	69	3/2	$\mu_{69}/\mu_{71} = 0{\cdot}79$.
		71	3/2	
33	As	75	3/2	
35	Br	79, 81	3/2, 3/2*	From bands I may be 5/2.
36	Kr	83	> 7/2	μ – ve.
37	Rb	85	5/2	$\mu_{85}/\mu_{87} = 0{\cdot}43$.
		87	3/2	
41	Nb	93	> 7/2	
42	Mo	95,97	?	I > 1/2 for at least one isotope. μ and isotope shifts small.
48	Cd	111	1/2	$\mu = -0{\cdot}62$.
		113	1/2	$\mu = -0{\cdot}62$.
49	In	115	9/2	
50	Sn	117, 119	1/2	$\mu = -0{\cdot}90$.
51	Sb	121	5/2	
		123	7/2	
53	I	127	9/2 or 5/2	From bands I probably large.
54	Xe	129, 131	1/2, 3/2	
55	Cs	133	7/2	
56	Ba	137	3/2?	
57	La	139	5/2	
59	Pr	141	5/2	
73	Ta	181	7/2	
74	W	183	?	I probably $\neq$ 0, and μ small.
75	Re	187, 189	5/2	
79	Au	197	3/2	
80	Hg	199	1/2	$\mu = 0{\cdot}6$.
		201	3/2	$\mu = -0{\cdot}6$.
81	Tl	203	1/2	$\mu_{203}/\mu_{205} \sim 1$.
		205	1/2	
82	Pb	207	1/2	$\mu_{Tl}/\mu_{Pb} \sim 4$.
83	Bi	209	9/2	

I values marked * are derived from intensity measurements in band spectra, the remainder from hyperfine structure analysis. If the two mass numbers are written on the same line, *e.g.* Br 79, 81, the two patterns were superposed. Where the I values were determined separately the mass numbers are written one above the other, *e.g.* Ga.

deserve special mention. They are two of the only four atoms of even mass but odd atomic number, the other two being Li^6 and B^{10}. The details are as follows :—

	H^2	Li^6	B^{10}	N^{14}
Z	1	3	5	7
M	2	6	10	14
I	1	0 ?	?	1

The result for Li^6 merely expresses the absence of observable structure ; it is a pity that the Li^6 bands are too weak to permit of any measurements of intensity alternation. Boron certainly appears to call for immediate investigation.

Certain other generalisations of a less striking character emerge from a study of the Table. For instance, of the 39 atoms listed, only 10 have odd atomic number (Z) although odd mass number (M) is associated with even atomic number about as frequently as with odd. The explanation is that nuclei of even Z and odd M are usually found in association with several other isotopes of much greater abundance, whereas nuclei for which Z and M are both odd never have more than one isotopic counterpart. The conditions of observation are therefore much more favourable in the latter case. But it is probably of real significance that for the former class I is always low, either 1/2 or 3/2, with the single exception of Kr, which does not carry much weight. On the other hand, high values of I are mainly confined to the simple (*i.e.* non-isotopic) elements. Thus, of the fourteen elements having $I > 3/2$, ten are simple and the remaining four have only two isotopes. It is of interest to note that the I values for two odd isotopes, although frequently identical, may differ, as in Rb, Sb, and Hg, and further that there is no direct association between I and μ. Both I and μ may be the same for the two isotopes (*e.g.* Cd, Tl), I may be the same but not μ (Ga), I and μ may both differ in the same sense (Rb), or the two μ's may be opposite in sign (Hg). There are several interesting sequences of successive odd mass numbers, in particular that from Cu to Br.

	Cu	Cu	Zn	Ga	Ga	Ge	As	Se	Br	Br
Z . .	29	29	30	31	31	32	33	34	35	35
M . .	63	65	67	69	71	73	75	77	79	81
I . .	3/2	3/2	3/2	3/2	3/2	?	3/2	?	3/2	3/2

There is a second complete sequence from Au to Bi, but here we have irregular variations of I.

	Au	Hg	Hg	Tl	Tl	Pb	Bi
Z . .	79	80	80	81	81	82	83
M .	197	199	201	203	205	207	209
I .	3/2	1/2	3/2	1/2	1/2	1/2	9/2

The sudden appearance of the large I value for Bi is very striking, but not unique, being paralleled in the case of In.

	Cd	Cd	In	Sn	Sn
Z	48	48	49	50	50
M	111	113	115	117	119
I	1/2	1/2	9/2	1/2	1/2

No simple type of periodicity or other regularity is discernible in the course of the I values over any considerable range, and it is unlikely that any very simple theory of nuclear structure will prove capable of accounting for them Various speculations have been advanced, but none of them goes very far towards explaining the facts and in any case discussion of them is outside the scope of this article. Attention may properly be directed, however, to some notable gaps in our present knowledge of nuclear moments, in addition to those which have already been mentioned. Among the lighter elements, particular interest attaches to the rare isotopes C^{13}, N^{15}, O^{17} and Ne^{21}. Of the elements of odd atomic number, Cl^{37}, Sc and Y are the only ones for which no data are as yet to hand, but very little is known concerning the elements of even atomic number. A comparison of the moments of isobaric nuclei should also repay investigation, although only two such pairs, Sr^{87} Rb^{87}, and Sn^{121} Sb^{121} appear to offer any reasonable prospect of success. The importance of further theoretical work which will place the determination of nuclear magnetic moments on a surer footing has already been indicated. The fragmentary information of this kind at present available does lead to one conclusion of primary importance, however. It is that the electron, if it exists at all in the nucleus as a separate entity, does not contribute to the magnetic moment of the latter, since this is of the order of one proton-magneton, *i.e.* 1/1840 of the electron- or Bohr-magneton.

ASPECTS OF THE STUDY OF WOOD ANATOMY

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With the increasing output of papers on wood anatomy during recent years, the work of the older investigators in this field appears to pass more and more into the background. This state of affairs is inevitable: nevertheless, their work should not be forgotten. Reference to the pages of Solereder [68] will show that considerable study had been devoted to the secondary xylem, particularly in Germany. Somewhat later, several botanists in the United States turned their attention to the study of wood anatomy, and a number of papers appeared, especially concerning coniferous woods and the nature of the rays in certain dicotyledonous families. Of the investigators who were particularly interested in wood from the applied side, the names of Boulger and Stone deserve mention: Stone's book [69], in particular, in which an attempt was made to provide a means of identifying commercial timbers, partly on their structure, is now quite out of date, and in the light of recent work leaves much to be desired; but when the difficulties under which the work was carried out are borne in mind—difficulties of obtaining authentic material, the difficulty of establishing suitable criteria for comparison in a pioneer work—it is a matter for surprise that so much was accomplished.

Modern wood anatomy may be considered as of post-War origin, although some work along modern lines had been started earlier. The lines upon which it has advanced have been dictated, to a great extent, by economic factors. It is safe to say that by far the greatest number of investigators in this field hold official positions in Government institutions; it is not surprising, therefore, that investigations have been chiefly upon woods of economic, or potential economic importance. Fortunately there are workers now in several universities, and even individuals working privately, who are, to a great extent, free to pursue any line of enquiry which interests them, regardless of its possible economic significance: it

is a good sign that in a number of investigations wood has been dealt with as a product of the plant, not as a commodity. Such work is a sure guard against the dangers of a purely technological outlook and the loss of contact with the corresponding branches of pure science, the maintenance of which is essential to progress. It is impracticable and undesirable to consider researches on the pure and applied science independently of one another; to the writer it seems that nowhere in botany do the two merge so imperceptibly into one another. However, it is convenient to consider first the main points of view which may be regarded as the outcome of economic pressure.

In recent years the need has been frequently felt for greater knowledge of the potential wealth of certain countries, in particular of those in tropical regions. One outcome has been the investigation of the timber resources of certain areas, sometimes coupled with descriptions of the chief woods: descriptions of this nature are often confined to macroscopic features, but anatomical details, sometimes of the most scanty nature, are included at times. A knowledge of anatomical details is of more importance, however, when the question of substitutes for woods of known quality is considered. There are two types of wood substitutes: (1) woods usually of inferior quality and less costly, which the unscrupulous attempt to supply in place of the timber required; (2) new or relatively unknown timbers which for some purposes may be of equal worth to better known woods. Timbers which fall into the second class are prominent at the present time, when much effort is being expended in introducing new woods upon the world's markets: merchants and users of woods not unnaturally treat new timbers with suspicion, preferring, where possible, to handle some well-known wood Efforts are often made to exploit a new wood by christening it with a name similar to some popular timber. Brownish-red woods frequently appear under the general designation of mahogany, and darker brown timbers as walnuts. Thus Queensland Walnut (*Endiandra Palmerstoni*), African Walnut (*Lovoa Klaineana*) and Satin Walnut (*Liquidambar styraciflua*) all have some supposed resemblance to true Walnut (*Juglans* spp.). A good deal of attention has been given to the study of such groups of timbers, with a view to differentiating the various woods by means more certain than mere inspection. Record and Garrat [62] have shown that the true boxwoods (*Buxus*, *Buxella* and *Notobuxus*) all possess vessels with scalariform perforations, whereas in substitutes, such as West Indian Boxwood (*Casearia præcox*), Knysna Boxwood (*Gonioma Kamassi*) and San Domingan Boxwood (*Phyllostylon*

brasiliensis), the vessels have simple perforations, except in Dogwood (*Cornus florida*); these authors have demonstrated the possibility of differentiating specifically all the boxwoods of commerce by more detailed anatomical studies. In the same way Record [59] has shown that it is possible to distinguish between the true walnuts and woods bearing similar trade names. It is equally simple to differentiate between teak (*Tectona grandis*) and its substitutes, such as African Teak (*Chlorophora excelsa*), Eng (*Dipterocarpus tuberculatus*) and Borneo Teak (*Dryobalanops* spp.), also between Ash (*Fraxinus excelsior*) and certain woods with a superficial resemblance to it, such as Hickory (*Carya* spp.), and Tree of Heaven (*Ailanthus glandulosa*), and similarly to distinguish Ebony (*Diospyros* spp.) from woods like Pear (*Pyrus communis*), Holly (*Ilex* spp.), and Hornbeam (*Carpinus Betulus*), which are sometimes dyed black to serve as substitutes for ebony. as far as the author is aware the means of differentiating the woods just noted have not appeared in print. The trade substitutes for mahogany—strictly the wood of the trees of the genus *Swietenia*—are legion. a key to the commercial mahoganies, based on their structure, was drawn up by Record [56], but with the increasing number of new " mahoganies " appearing on the world markets, this is a task which might well be undertaken again.

In other instances attempts are made to interest users in a timber only after it has been subjected to exhaustive scientific tests. The study of wood anatomy, coupled with researches on the physical and mechanical properties of a wood, and a study of its defects and seasoning qualities, renders it possible to predict, to some extent, suitable uses for a new wood. Investigations of this nature are summarised in certain of the publications of the Forest Products Laboratory at Princes Risborough, of which mention may be made of the pamphlets on Corsican Pine (*Pinus Laricio*) [27], Scots Pine (*Pinus sylvestris*) [28], Purpleheart (*Peltogyne ? pubescens*) [30], and Indian-grown Honduras Mahogany (*Swietenia macrophylla*) [31]. Of particular interest as a demonstration of the value of wood anatomy on the applied side is the study of Sapele Mahogany (*Entandrophragma* spp.) [29], in which bulletin the possibility of the use of these woods for the manufacture of airscrews is considered; it would appear to be imperative to be able to identify with certainty the wood of which these articles is made, and it is shown that this is possible in the case of the three species of *Entandrophragma* with which the investigation deals. Publications of a somewhat similar nature to those just mentioned are issued by the Association Colonies-Sciences et Comité National des

Bois Coloniaux, on woods of the French colonies [1] [2]. A number of shorter papers has also appeared, usually dealing with one or more woods relatively new to commerce. Of these mention may be made in particular of those on *Chlorophora excelsa* [11] and *Triplochiton scleroxylon* [10], under the joint authorship of a scientist and a commercial man; this combination of two authorities, one on the commercial side and the other a wood anatomist, is one which might be more widely emulated. That investigations which consider anatomy in relation to mechanical strength may be profitably conducted upon the commonest woods is demonstrated by the recent work of Clarke [23] on Ash (*Fraxinus excelsior*); he has shown that for the same specific gravity there is a decrease in mechanical strength as the proportion of summer wood in the annual ring increases, and conversely that for a given proportion of summer wood in the annual ring, an increase in specific gravity is accompanied by an increase in mechanical strength, owing to the increased thickness of the fibre walls.

Another aspect of the subject which may be regarded as the outcome of economic conditions is the appearance of several keys designed to facilitate the identification of certain artificial groups of woods. Of these mention may be made of that on British Hardwoods by Chalk and Rendle [16], Chowdhury's pamphlet on Indian Sleeper-woods [21], and Hale's paper on woods commonly used in Canada [40] Papers of this type would appear to be designed with a view to enabling the person who handles timber to identify the types with which he deals, but it may be questioned how far they fulfil this function; probably few practical men carry a pocket lens and sharp penknife to enable them, even where practicable, to identify timbers in the manner set forth in such publications; identification of woods, even by the simple methods prescribed, calls for a certain amount of experience; the practical man will probably continue to make his identifications by general inspection—often a surprisingly accurate method to one with experience at handling woods—and to refer his difficulties to the wood anatomist.

Investigations in wood structure less influenced by economic considerations, may now be reviewed. A number of papers have appeared which contain descriptions of the wood anatomy of a few trees having little or no relation one to another; the value of such researches is small; the comparative ease with which such a paper can be produced may make an appeal to a certain type of mind, but such purposeless investigations are likely to lead to stagnation, and have little to recommend them either on scientific

or technical grounds. On the other hand the study of a group of related timbers—genus or family—with a view to their identification, may be of considerable value in providing information as to the possible range of structure among allied species. Such investigations are those of Welch on Australian Saxifragaceæ [74], Monimiaceæ [76] and *Agathis* [75], and Rol on *Pinus* [65]. That of Dadswell and Burnell [26] dealing with identification of coloured woods of the genus *Eucalyptus* merits comment: the woods of some thirty-seven species are described in detail and the results summarised; a successful attempt has been made to provide a key for the separation of the woods of different species; in the construction of this key the authors have not hesitated to make use of features other than anatomical ones; thus density and nature of the ash are also used: a feature which adds to the value of this study is that in most cases ten or more samples of each species taken from different localities were examined; hence the descriptions probably represent an average for the species.

The description of woods from one country appears to be a popular method of selecting a group for study, if one may judge by the number of publications which have dealt with this aspect of the subject. Some papers of this type are of such limited scope that they are of little more worth than a series of isolated descriptions; others, which deal with a large number of species are of great value for the identification of timbers. It is possible to mention only the more outstanding examples here. The great work of Moll and Jansonnius [51] on the structure of Javan woods is the most complete work on wood anatomy of a limited area. Pearson and Brown [53] have recently dealt with the Indian timbers; this work is less ambitious in its scope, aiming at describing some 300 timbers of commercial or potential commercial value; the limitations thus imposed upon the book may be defended on the grounds that these are the woods most likely to fall into the hands of wood anatomists outside India; nevertheless, it is a book which is likely to prove of more use to the applied side of the subject in the future: a feature of the book which is likely to be of great value to the botanist, however, is the summary for each family dealt with, of the anatomical characters of the secondary wood. In the *Timbers of Tropical America* [63] the subject is treated in rather a different manner: the book may be regarded as a pioneer work on the timbers of this region: it was obviously impossible to furnish complete descriptions of all the woods occurring in this part of the world and detailed descriptions are confined to one species of a genus; in this book also, an attempt is made to sum-

marise as far as possible the anatomical features of the families. Among other works dealing with the timbers of a restricted area are those of Brown on Hawaiian woods [12], Kanehira on the woods of Formosa [43], Japan [44] and the Philippine Islands [45] and Tang on Chinese woods [71] [72]. A work on East African Conifers and Leguminosæ [14], produced by the Imperial Forestry Institute, appeared recently, and is the first of a series dealing with the forest trees and timbers of the British Empire; each species is dealt with probably more fully than in any other work of a similar nature, and descriptions of species have been included only after a suitable supply of reliable samples has become available: the appearance of further volumes of this series will be awaited with interest. Along somewhat different lines is the work of Baker on Australian hardwoods [6]. In this volume the anatomical features of many of the woods are described, although the descriptions are often meagre; the value of this work and of the older volume on Cabinet Timbers of Australia [5] lies in the magnificent colour plates, depicting the actual appearance of the prepared timber.

Panshin's study of the woods of trees of the Philippine Mangrove swamps [52] gives a new orientation to research in wood anatomy. Some twenty-five species from about twelve different families were investigated It was noted that the woods had certain features in common, for example, fine texture, generally numerous vessels, and fairly abundant wood parenchyma usually best developed round the vessels; but it was concluded that habitat does not impress any definite type of anatomical structure upon different species, a conclusion which is in agreement with the hypothesis advanced by Solereder [68]. Hyde's [41] examination of seven light-weight woods from the tropics, from trees with large, soft leaves, thick, strong, fibrous bark and white or pale coloured woods suggests the possibility of generalisations on an ecological basis.

A type of investigation which illustrates the value of a knowledge of structure to the botanist, rather than to the wood technologist, is that in which the anatomy of the woods of a supposedly natural group is studied in relation to taxonomy. As far back as 1887 Saupe [66] studied the anatomy of the wood of the Leguminosæ, and found anatomical groups which coincided more or less with Bentham and Hooker's classification of the family. More recently Kribs has studied the Juglandaceæ [46] and Meliaceæ [47], den Berger the Dipterocarpaceæ [8], and Jansonnius the Euphorbiaceæ [42], along similar lines. With the same aim in view Chattaway [19] investigated the parenchyma of the section Sterculeæ of the Sterculiaceæ, and on the basis of its abundance and method of

occurrence, concluded that the existing classification requires revision ; in particular she has suggested that *Tarrietia* and *Heritiera* should be removed from this section of the family, a conclusion which seems justified by morphological considerations. McLaughlin [48] has studied the anatomy of the secondary xylem of the Magnoliales (of Hutchinson) ; his researches have led him to suggest the removal of a number of genera from the order, and he concludes that the Magnoliales comprises the families Magnoliaceæ and Schizodendraceæ, the two families forming a natural group both anatomically and morphologically : he proposes the separation of the Winteranaceæ, Trochodendraceæ and *Tetracentron* as a new order, or at least, as a separate sub-order. Garratt's study of the Myristicaceæ [38] leads the author to conclude that Warburg's classification of this family is a more natural one than those of Bentham and Hooker or De Candolle. Carefully conducted studies of this nature call for consideration from taxonomists, especially where morphological features, of a type usually considered of taxonomic value, are considered, in addition to wood anatomy.

A further development along taxonomic lines is seen in the work of Sax and Abbe [67] on the Oleaceæ. These authors have examined the structure of the secondary xylem and have also investigated the chromosomes of a number of species : they find a certain parallelism between chromosome number and anatomy, and also grafting relationships. Such investigations, which are not limited to wood anatomy, are of considerable interest and value.

Another line of taxonomic studies suggests that wood anatomy may prove of value in palæobotany. Tupper [73] was led to make a study of lauraceous woods because it is generally held that the wood of this family is characteristic and easily identified, hence the frequent recognition of fossil woods as *Lauroxylon*. He noted the wide variation in woods of the family, the only constant character being the presence of marginal ray cells ; for this reason he considers it desirable that fossil woods should be referred to existing genera rather than the family ; he is convinced that many fossils described as *Lauroxylon* are actually referable to different and widely separated families. One is inclined to question the possibility of referring fossil woods to existing genera in a family such as this, where it is not always possible to establish generic distinctions between the timbers, and to share the general opinion that lauraceous wood is characteristic and not difficult to identify ; after all, the identification is made from an aggregate of characters, not from any single feature.

A number of recent papers have dealt with aspects of wood

anatomy which are of greater importance from the point of view of pure botany. Thus, Bailey's work on cribriform or vestured pits [3] [4] has demonstrated that the old view that the cribriform pit contains a perforated membrane is often erroneous, and that the punctate appearance may actually be due to minute outgrowths from the wall of the pit Chalk [13] has described the multiperforate plates occurring in vessels, and has given an account of their distribution and range of form, while the same author, in collaboration with Chattaway [15], has investigated a peculiar type of ray cell in which the side walls are perforated and connected to two series of vessel segments, one on either side of the ray. Chattaway [20] has examined the radially flattened cells (tile cells), which occur in the rays in certain members of the Malvaceæ and allied families, and has traced their development from the cambium, showing that they divide repeatedly after they have been differentiated from the cambium, and later lose their contents. A summary of the distribution of intercellular canals has been drawn up by Record [58], while detailed investigations of these structures have been made by Groom [39] in the Meliaceæ, and by Welch [77] in *Flindersia* spp.

Under the leadership of Priestley members of the Leeds School of Botany have conducted investigations upon the living tree, with particular reference to the activities of the cambium and the ascent of sap [54] [55]. The angle of approach is both novel and interesting, and the anatomical work arising from it furnishes useful confirmation of the researches of the older plant anatomists [78].

The use of features other than anatomical ones as a means to identification is a direction of attack which is being profitably pursued by certain workers, particularly in Australia. Cohen [24] has shown that it is possible to differentiate with certainty between the wood of Hoop Pine (*Araucaria Cunninghamii*) and Bunya Pine (*A. Bidwilli*) by means of chemical tests: to an aqueous extract of the sawdust sulphuric acid is added; in *A. Bidwilli* a pink colour develops immediately, followed by an orange precipitate; in *A. Cunninghamii*, there is no immediate change, but a white gelatinous precipitate eventually forms: the pink colour is regarded as the more reliable indicator. Of forty-eight samples investigated all but one gave the expected reaction, and the exceptional sample proved to be of questionable authenticity. Dadswell [25] has turned his attention chiefly to species of *Eucalyptus*, and finds that it is possible to distinguish between Karri (*E. diversicolor*) and Jarrah (*E. marginata*) with certainty, since the alkalinity of the

ash of the former has a value of at least twice that of Jarrah. Similar experiments with somewhat similar woods, Tallowwood (*E. microcorys*), Blackbutt (*E. pilularis*) and White Mahogany (*Eucalyptus* spp.) did not prove sufficiently conclusive for the separation of Blackbutt and White Mahogany, and a further test was elaborated in which an alcoholic extract of the sawdust was made and diluted with water; the result was an immediate white turbidity in Tallowwood and White Mahogany; in Blackbutt, however, the diluted extract remained clear, for some time at least: the turbidity differed according as to whether Tallowwood or White Mahogany sawdust was used; in the latter case a white precipitate was eventually thrown down, and this was held up by the filter paper when the solution was filtered; it was not possible to obtain a clear filtrate from the Tallowwood extract. Relatively simple chemical tests on the reddish-brown woods of Red Box (*E. polyanthemos*) and Red Gum (*E. rostrata*) indicated that these two woods could be differentiated with certainty by chemical tests.

Previous to the publication of these papers a certain amount of rather unmethodical work had been done on the chemical reactions of certain timbers. Stone investigated the reactions when certain woods were treated with a number of simple reagents and Kanehira [43] elaborated a test for the flavone content. An analysis of European and North American woods has shown that it is possible to distinguish between various genera chemically, but the utilisation of relatively simple qualitative tests for the identification of closely allied species is a line which it is hoped will be further developed in the near future.

Certain very real difficulties have for a long time formed a bar to rapid progress in the study of wood anatomy. Chief among these has been the difficulty of obtaining authentic material. Trade samples of the commoner woods are usually easy to acquire, but a trade-name may designate a group of botanical species or even genera, so that the authenticity of the sample may be open to question. English Oak is certainly sometimes *Quercus robur*, sometimes *Q. sessiliflora*: Selangan Batu from Borneo consists of wood from *Isoptera borneensis* and from a species of *Hopea*. The difficulty is enhanced where tropical woods are concerned. The assurance that a sample is a specimen of a timber bearing a certain trade-name is by no means proof that this is so; parcels of timber sometimes contain odd pieces of entirely different woods; an extreme case was that of a specimen received by the writer recently with the categorical statement that it was wood of an American Elm; it was actually Poplar, of which a log had evidently been shipped

with the elm in error. To some extent the difficulty of obtaining authentic material is overcome by making use of specimens supplied by Forest Officers and Government Departments; even so, it is not to be expected that every Forest Officer is a skilled systematist, and there is appreciable risk of confusion between closely allied species. The only satisfactory method is to use wood obtained from trees from which herbarium material has been taken. The practice of collecting herbarium material with wood specimens is pursued as far as possible in the larger institutions. Partly with a view to facilitating the exchange of material for research the International Association of Wood Anatomists was recently founded, and an account of the aims of the Association is to be found in a paper by Record [61]: the writer has experienced the ready response with which any request to members of the association for research material is met. With critical genera it would, of course, be unwise to attempt any serious anatomical investigations unless ample material were at hand: none would suggest a study of woods of the genus *Eucalyptus* or of the Dipterocarpaceæ by anyone other than a resident in those countries in which the trees abound.

Another difficulty which exists, especially for the private worker, is the scattered nature of the literature on wood anatomy: much time is often spent in searching for known papers, even in the libraries in London: the difficulty of keeping in touch with literature as published is great. Fortunately a good deal of the current literature is summarised in certain journals; special mention may be made of the valuable abstracts and reviews in the *Empire Forestry Journal* and in *Tropical Woods*; the last publication, incidentally, does not confine its activities entirely to the timbers of tropical countries. In *Tropical Woods* notices of proposed researches in wood anatomy by members of the International Association of Wood Anatomists are published, hence there is little danger of overlap in investigations.

Methods of describing the structure of woods call for comment. It would appear that, as a general rule, too little notice is taken of the variations which are known to occur in wood of a single species. Within the last few years several investigators have demonstrated that there exists a considerable range of structure in a single bole. Clarke [22], working on three species of Elm (*Ulmus campestris*, *U. major* and *U. montana*), found an increase in the size of the elements of the progressively older wood until the adult stage was reached, when the size of the elements remained relatively constant, he also noted an increase in the size of the elements of any one annual ring from below upwards, until a maxi-

mum was reached, followed by a decrease; it was further found that wood produced in later life generally has a smaller proportion of mechanical tissue than young wood. Desch [33] noted an increase in fibre length up to a certain height in the trunk and then a decrease to the top of the tree, while Chattaway [17] found the most striking variation in vessel pattern and amount of parenchyma in a disc of Sapele Mahogany (*Entandrophragma cylindricum*), pointing out that it would have been difficult to identify the wood as *Entandrophragma*, from one part of the disc alone. Nevertheless, descriptions of a most detailed nature are often published, every element being carefully considered as regards form, dimensions and distribution. Without suggesting that descriptions containing scanty detail—and many such exist—are all that is required, it is difficult to avoid the conclusion that the former type of description is carried to excess. In any case it is reasonable to expect that detailed accounts should at least emphasise the average for the species under consideration, and should be based ideally on a sufficiently large number of samples taken from different parts of the range of the species and from as varied habitats as possible, and also from different parts of the tree, to allow for variation in a single trunk. It will, of course, be urged that this is a counsel of perfection, which can rarely be realised; but under such conditions it may be suggested that the making of detailed descriptions is wasted time. Descriptions of woods should be of such a nature as to enable a reasonably experienced person to identify an unknown specimen by their aid; few such would have the inclination, even if time permitted, to make the large number of measurements of all the elements of a wood, as many descriptions require; nor would they know, as a rule, that the writer of the description had himself taken a sufficiently large number of readings to make the measurements significant. Clear concise descriptions, with the salient features stressed, and as far as possible independent of size, should prove of much greater value. An argument that might be advanced in favour of measurements is that, until our knowledge of wood structure is much more extensive than it is at present, we are not in a position to predict what features may be of value in identification; to some extent this is true, but a study of the available woods of a family may show what features are likely to be of value in differentiating allied woods: the diagnostic features are certainly not always those of size, a fact which is well brought out in the key which Dadswell and Burnell [26] have made for the identification of the coloured *Eucalyptus* woods. Where measurements are taken it ought to be with a due regard for the laws of

probability. Desch's valuable papers [32] [33] on the significance of numerical values for cell dimensions demand the careful attention of all students of wood anatomy. Without suggesting the abandoning of the practice of recording measurements, he doubts whether the use of figures is likely to be of much value except in special cases: he shows that means should be based on at least 300 measurements to make differences between them significant, and stresses the necessity of giving the number of measurements of which the figure given is the mean, and also indications of the method used for sampling.

Chattaway [18] has proposed a series of standards for numerical values which deserves consideration when any attempt is made to standardise the terms used in describing woods. Beverslius [9] points out that, with the constant arrival of new material, some universal method of description is required. It may be hoped that the near future will see both a standardised nomenclature and a standardised type of description adopted by wood anatomists.

A means of stressing the salient features is the use of clear diagrams of transverse and longitudinal sections. Such diagrams, drawn to a suitable magnification, would often prove more helpful than photomicrographs; the latter, it is true, may give a faithful picture of the specimen, but their production, especially those depicting high magnifications, requires considerable skill, and even in the most perfect, important diagnostic features may not be clearly shown: the chief limitation in their usefulness is lack of depth. The use of diagrams as text figures, in place of photomicrographs, which, to do them justice, require to be reproduced as plates, has also much to recommend it on the ground of economy. Such a view as that just advanced is not likely to meet with general acceptance; there would appear to be a general opinion that a photomicrograph, because it is, or is supposed to be, a faithful reproduction of the original, is necessarily of greater value than a figure.

Recent attempts to study wood anatomy in the light of taxonomy call for careful consideration. It is usually regarded as almost axiomatic that the parts of a plant which are most used in its normal metabolism are the least reliable taxonomic guides: it is, therefore, reasonable to question the value of the secondary wood as an indicator of affinities. No fault can be found, however, with Record's careful statement [60]: he points out that the basis of segregation of plants into families, genera and species is primarily the morphology of the reproductive organs and that interpretations of the facts concerning these organs are constantly open to question;

he argues that a nearer approach to a natural classification would be to study every plant in its entirety and that consequently wood anatomy is one of the branches capable of helping in the solution of taxonomic problems : he further stresses the danger of an attempt to classify woody plants solely on the basis of their wood. Garratt [37] has pointed out that while individual anatomical features may appear in woods of several families, the combination of anatomical features (the structure as a whole) is characteristic of many individual families and not paralleled in others. It is a significant fact that it is often possible for a wood anatomist to decide correctly to what family an unknown wood belongs, even after the most cursory examination. Further, Panshin's work, already noted, indicates that habitat does not produce any striking change in anatomy, as far as the secondary wood is concerned. At the same time, if the taxonomist is to receive assistance from studies in wood anatomy, every care must be exercised to avoid hasty conclusions. Thus it is doubtful if much significance can be attached to such work as that of Tang [70], who, from the examination of a single specimen of *Rhoiptelea chiliantha*, with only eleven growth rings, concludes that the wood agrees more with the Ulmaceæ than with the Juglandaceæ. Careful studies like those of Frost [34] [35] [36] on the lines of specialisation in the secondary xylem in dicotyledons should prove of great assistance in the study of wood anatomy from the standpoint of taxonomy.

In connection with taxonomy, it has been urged that if the wood of closely allied species be examined with sufficient care, some point or points of difference will eventually be detected. It is difficult to agree with this view, particularly when dealing with genera which may be regarded as in the process of rapid evolution, *e.g. Eucalyptus*, *Nothofagus*, *Acacia* : it would be conceded that the rate of evolutionary progress varies for different parts of the plant ; thus two variants of a single stock might well differ sufficiently in their morphological characters to be listed as different species, although an examination of their secondary xylem would reveal no difference.

The present position of wood anatomy has been summarised by Martley [50] and by Rendle [64]. It may perhaps be compared with that of British Botany in the nineteenth century, when, with the opening up of new lands the activities of botanists were largely concentrated upon labelling, describing and classifying new plants. In the same way, as plant products of new countries become more available, the wood anatomist is devoting his energies largely to describing new woods. This state of affairs is inevitable, nor would

one suggest that it is unnecessary; but just as botany has emerged from the position of a purely descriptive science, so may similar developments be looked for in wood anatomy. Signs are not wanting that this evolution is already taking place. Enough has already been said to indicate that the study of wood anatomy is not entirely in the descriptive rut. As to future development, it is difficult to prophesy, but several possible lines may be suggested. On the applied side it seems likely that the chief line of advancement will be the attempt to correlate structure with the properties of the wood—physical, mechanical and chemical—with its seasoning and working qualities, and with the defects to which the timber is liable. Such studies will doubtless be extended to new woods, with a view to supplying information as to probable uses for which the wood is suited, and there is little doubt that the same line of enquiry will be applied intensively to well-known woods, with a view to ascertaining the range of variation within a species. From the standpoint of pure botany also, extensive studies of the structure of the secondary xylem in relation to habitat are much to be desired; one of the chief difficulties in the way of such an investigation is the lack of suitable material; available specimens rarely bear sufficient data as to locality and nature of habitat; however, the acquisition of material for such a study should prove possible; in this country there must be many trees which are of little commercial value and from which samples could be obtained with the aid of a borer; these would probably prove sufficient, at least for a preliminary survey, and little or no damage would be suffered by the tree were borings filled immediately with some antiseptic substance: nor need the study be made on a species of commercial importance; a tree such as Hawthorn (*Cratægus* spp.) should serve equally well. Further studies which might throw light on the lines of development within a family would be those which dealt with the comparative anatomy of the xylem in a family represented by herbaceous, shrubby and dendroid species; for example the Rosaceæ or Leguminosæ, which include a wide range of habit from practically every type of habitat, suggest suitable material for such a line of investigation. Such studies might throw light on the evolution of different types of plant habit, apart from any phylogenetic significance which they might possess. Reference to the paper of Bancroft [7] on the arborescent habit in Angiosperms reveals that a good deal of research along these lines has already been published, but largely, it would appear, with a view to determining whether the arborescent or the herbaceous habit is the more primitive. The line of investigation suggested above would

involve a wider field, with considerations of both phylogenetic and ecological significance.

Data of value in the study of evolution might be made available from a study of the young and mature wood of a series of related arborescent plants; it is known that young and mature wood may differ (*e.g.* Clarke [22]), and assuming that the structure of a timber is more or less constant under whatever conditions the tree grows, in other words, that the inherited characters of the wood are sufficiently abundant, such investigations might give some insight into possible phylogenetic trends within a group. How far it is possible to demonstrate that ontogeny repeats phylogeny in the secondary xylem is at present not known.

Development may also be expected along the lines of studies in extra floral characters which may serve as a means of identifying species. Several studies in the structure of the bark have already been made, but much remains to be accomplished. It may be hoped that, in the future, descriptions of the structure of woods, and especially those designed for the practical man, will as far as possible include descriptions of the bark. Record [57], in his investigation of Lignum Vitæ (*Guaiacum* spp.), has already shown that the bark may be of diagnostic value. Investigations on the general anatomy of twigs of allied trees might prove a helpful line of enquiry. In connection with these aspects of the subject, however, it ought not to be forgotten, if repetition is to be avoided, that a great deal of work on such lines has already been accomplished by students of pharmacognosy: a case in point is the detailed knowledge which exists regarding the anatomy of the *Cinchona* barks.

It is to be expected that further advances will be made in designing relatively simple chemical tests as an aid to distinguishing between woods which cannot be separated with certainty by visual means. It may be hoped also that in future closer attention will be paid to the identification of the amorphous and crystalline substances which are encountered in the elements of the wood; it should not be considered as adequate to describe some material as a white deposit. It is not improbable that interesting results may be awaiting the investigator in this field. The researches of McNair [49] on gums, resins, tannins, oils and waxes, in relation to environment and function, suggest possible fruitful lines of enquiry.

It may be suggested that the most successful results are likely to attend future investigations which treat of wood as a plant product, and not merely as a real or potential commodity.

LITERATURE CITED

1. Assoc. Col. Sciences & Com. Nat. des Bois Col., *Monogr. Scientif., No. 2*, 1928.
2. — *Monogr. Scientif., No. 3*, 1929.
3. Bailey, I. W., *Trop. Woods*, **31**, 46–8, 1932.
4. — *J. Arnold Arb.*, XIV, 259–73, 1933.
5. Baker, R. T., *Cabinet Timbers of Australia*, Tech. Mus. Sydney, Tech. Ed. Ser. 18, 1913.
6. — *The Hardwoods of Australia*, Tech. Mus. Sydney, Tech. Ed. Ser. **28**, 1919.
7. Bancroft, H., *New Phytol.*, XXIX, 153–69, 227–75, 1930.
8. den Berger, L. G., *Bull. Jard Bot. Buitenzorg.*, **8**, 495–8, 1927.
9. Beversluis, J. R., *Congrès Int. Bois et Sylvicult.*, Paris, 1931.
10. Boulton, E. H. B., and Price, T. J., *Trop. Woods*, **25**, 3–4, 1931.
11. — — *Trop. Woods*, **28**, 4–7, 1931.
12. Brown, F. B. E., *Occas Pap. Bern. Pau Bish., Mus.*, Hawaii, VII, 6, 1922.
13. Chalk, L., *Forestry*, VII, 16-25, 1933.
14. Chalk, L., Davy, J. Burtt, and Desch, H. E., *Forest Trees and Timbers of the British Empire*, 1, Oxford, 1932.
15. Chalk, L., and Chattaway, M. M., *Proc. Roy. Soc.*, B. **113**, 82–92, 1933.
16. Chalk, L., and Rendle, B. J., *British Hardwoods, their Structure and Identification*, London, 1929.
17. Chattaway, M. M., *Empire Forest. Journ* , **10**, 263–5, 1931.
18. — *Trop. Woods*, **29**, 20–28, 1932.
19. — *New Phytol* , XXXI, 119–32, 1932.
20. — *New Phytol.*, XXXII, 261–73, 1933.
21. Chowdhury, K. A., *Forest Bull., No. 77, Econ. Ser.* Calcutta, 1932.
22. Clarke, S. H., Dept. Sc. and Ind. Res., *For. Prod Res. Bull. 7*, 1930.
23. — *Forestry*, VII, 26–31, 1933.
24. Cohen, W. E., *Journ. Council Sci. Ind. Res. Melbourne, Reprint 13*, May, 1933.
25. Dadswell, H. E., Council Sci. Ind. Res., Melbourne, *Pamphlet No. 20*, 1931.
26. Dadswell, H. E., and Burnell, M., Council Sci. Ind. Res. Melbourne, *Bull. No. 67*, 1932.
27. Dept. Sci. and Ind. Res., *For. Prod. Res., Bull. 6*, 1930.
28. — *For. Prod. Res., Bull. 15*, 1931.
29. — *For. Prod. Res. Lab., Proj. 22*, Invest. 4/A.
30. — *For. Prod. Res. Lab., Proj. 22*, Invest. 11.
31. — *For. Prod. Res. Lab., Proj. 23*, Invest. 6.
32. Desch, H. E., *Trop. Woods*, **29**, 14–20, 1932.
33. — *New Phytol*, XXXI, 73–118, 1932.
34. Frost, F. H., *Bot. Gaz.*, **89**, 67–94, 1930.
35. — *Bot. Gaz.*, **90**, 198–212, 1930.
36. — *Bot. Gaz.*, **91**, 88–96, 1931.
37. Garratt, G. A., *Trop. Woods*, **33**, 45, 1933.
38. — *Trop. Woods*, **35**, 6–48, 1933.
39. Groom, P., *Ann. Bot.*, XL, 631–49, 1926.
40. Hale, J. D., Dept. Interior, Canada, *For. Bull. 81*, 1932.
41. Hyde, K. C., *Bot. Gaz.*, **79**, 380–411, 1925.

42. Jansonnius, H. H., *Trop. Woods*, **19**, 8–10, 1929.
43. Kanehira, R., *Anatomical Characters and Identification of Formosan Woods*. Taihoku, Formosa, 1921.
44. — *Identification of Important Japanese woods*. Taihoku, Formosa, 1921.
45. — *Identification of Philippine Woods*. Taihoku, Formosa, 1924
46. Kribs, D. A., *Trop. Woods.*, **12**, 16–21, 1927.
47. — *Amer. J. Bot.*, **17**, 724–38, 1930.
48. McLaughlin, R. P., *Trop. Woods.*, **34**, 3–39, 1933.
49. McNair, J. B., *Amer. J Bot.*, 17, 187–96, 1930.
50. Martley, J. F., *Forestry*, II, 62–68, 1928.
51. Moll, J. W., and Jansonnius, H H., *Micrographies des Holzes . . . Java*. Leiden, 1906
52. Panshin, A. J., *Philipp J. Sci.*, **48**, 143–207, 1932.
53. Pearson, R. S., and Brown, H P., *Commercial Timbers of India*. Calcutta, 1932.
54. Priestley, J. H., *New Phytol.*, XXIX, 56–73, 96–140, 316–354, 1930.
55. — *Rep. Brit. Assoc. Adv Sci*, 1932, 185–208.
56. Record, S. J., *J. For*, XVII, 1/8, 1919
57. — Yale School of Forestry, *Bull. 6*, 1921.
58. — *Trop. Woods*, **4**, 17–20, 1925.
59. — *Trop. Woods*, **18**, 4–29, 1929.
60. — *Empire Forest. Journ*, **10**, 5–6, 1931.
61. — *Bull. Torrey Bot. Cl.*, **59**, 29–33, 1932.
62 Record, S. J., and Garratt, G. A., Yale Univ. School of Forestry, *Bull. 14*, 1925.
63. Record, S J., and Mell, C. D., *Timbers of Tropical America* New Haven, 1924.
64. Rendle, B. J., *Nature*, **130**, 834–6, 1932.
65. Rol, R., *Rep. 65th Congrès des Soc. Savantes*, 333–41, 1932.
66. Saupe, A., *Flora, Jena*, 258–68, 275–82, 1887.
67. Sax, K., and Abbe, E. C., *J. Arnold Arb*, XIII, 37–48, 1932.
68. Solereder, H., *Systematic Anatomy of the Dicotyledons* Oxford, 1908.
69 Stone, H., *The Timbers of Commerce*. London, 1904.
70. Tang, Y., *Bull. Fan Mem. Instit. Biol.*, III, 10, 1932.
71. — *Bull. Fan Mem. Instit. Biol*, III., 13, 1932
72. — *Bull. Fan Mem. Instit. Biol.*, III, 17, 1932.
73. Tupper, W. W., *Amer. J. Bot.*, **14**, 520–4, 1927.
74. Welch, M. D., *J. Roy. Soc. N.S.W.*, LIX, 276–92, 1926.
75. — *J. Roy. Soc. N.S.W.*, LXI, 248–66, 1927.
76. — *J. Roy. Soc. N.S.W.*, LXII, 350–65, 1928.
77. — *J. Roy. Soc. N.S.W.*, LXIV, 352–62, 1930.
78. Wight, W., *New Phytol.*, XXXII, 77–96, 1933.

THE EARLIEST PORTRAIT OF JOSEPH PRIESTLEY

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In a recent communication (*Nature*, 1933, **131**, 876) one of us (W. C. W.) published the first reproduction of the earliest portrait of Joseph Priestley with a request for information as to the present whereabouts of the original, all trace of which appeared to have been lost since 1860. A reproduction also appeared in this journal (1933, **28**, 26). These copies were made from a photograph taken by Messrs. Caldesi, Blanford & Co., 13 Pall Mall East, London, in 1860 and now preserved in the Canton papers in the Library of the Royal Society. According to the legend printed beneath the photograph, the original was formerly in the possession of William Hudson of Gildersome, near Leeds. This was the only fact available.

The appeal for information gave no satisfactory clue, but extensive private enquiries have recently enabled us to locate the portrait and to give some account of its history. Although we are unable to divulge the identity of the owner, we have permission to state that it is in a private collection of family portraits in the possession of a granddaughter of Mrs. Bilbrough (*née* Ellen Priestley) now living in Cheshire.

Since the location of the portrait, other Caldesi Blanford prints have been found, two in the Reference Library, Leeds, one in the Yates Priestley Memorial Volume in the Library of the Royal Society and one in the National Portrait Gallery. We find from documents in the Yates Collection that the latter print was sent to the National Portrait Gallery for record purposes, while other letters preserved there enable us to trace the history of the portrait up to 1865 and to explain how it came to be photographed in 1860. Yates's interest in Priestley and his labours in connection with the erection of the statue of Priestley in the Oxford Museum arose from his distant relationship to Priestley, and the former ownership of the portrait by William Hudson of Gildersome is similarly explained. Ellen

Priestley's father (Brooks Priestley of Liverpool), William Hudson of Gildersome and the mother of James Yates, F.R.S., were cousins: they were descendants of three sisters who were granddaughters of John Priestley of Fieldhead, uncle of Joseph Priestley. Mrs. Bilbrough (Ellen Priestley) and James Yates were therefore both great-grandchildren of John Priestley.

It appears that the picture was taken to Gildersome, near Leeds, by Priestley's widowed sister Martha (Mrs. Crouch) in 1787, when she moved from Fieldhead to keep house for her relative, William Hudson of Park House, Gildersome. After the death of Mrs. Crouch in 1812, Hudson invited Ellen Priestley and her husband, James Bilbrough, to make their home with him at Park House; and, on his death in 1829, he left the house and other effects to Mrs. Bilbrough who continued to live there until she died in 1865. "Soon afterwards," according to a note in the Yates Collection, "her two unmarried daughters removed to Bury in Lancashire, taking the portrait with them." Mrs. Bilbrough had bequeathed the portrait together with nine other family portraits to one of her daughters with instructions that they were never to be separated. She in turn left them to a married sister with the same instructions. They are now in the possession of this lady's only surviving daughter.

Referring to the portrait in his *Memorials of Dr. Priestley* (1860), Yates says: "I first knew this picture and heard Mrs. Crouch speak of it as the portrait of her 'brother Doctor' more than fifty years ago." In the same pamphlet, writing of Hudson and Gildersome, he says: "Here I used to visit him, and saw the picture. It has always hung there in the dining-room with other family portraits. It has been highly valued by its possessors, who have been unwilling to part with it on any terms."

From the letters that passed between Mrs. Bilbrough and Yates in 1860, some of which are preserved in the Yates Collection and others in the possession of descendants of Mrs. Bilbrough, we are now able to account for the Caldesi Blanford prints. In 1860, Mrs. Bilbrough lent the portrait to Yates in order that it might be studied by Stephens, the sculptor who had been commissioned to execute the Oxford statue. While in London from February to June, it was exhibited in Dr. Williams's Library, and Yates had a number of photographic copies made for presentation to those who had subscribed towards the erection of the statue. It was also exhibited at a Royal Society soirée given at Burlington House on March 3, 1860, by Sir Benjamin Brodie, P.R.S., and in the rooms of Colnaghi, the print-seller, in Pall Mall.

It is clear from the Bilbrough-Yates correspondence that an

unsuccessful attempt was made to discover the date of the portrait and the identity of the artist. In Leeds, Mrs. Bilbrough failed to learn anything from the Mill Hill Chapel records, while Yates sought the advice of Colnaghi, "the eminent print-seller in Pall Mall," to whom he also says he "entrusted it . . . to make a photograph of it." Evidently Colnaghi employed Messrs. Caldesi, Blanford & Co., his neighbours, to carry out this work. Colnaghi appears to have been unable to identify the artist or to ascribe a definite date to the picture, since Yates arranged for the following legend to be printed under the photographs: "Joseph Priestley, ætat 30, from a portrait formerly in the possession of William Hudson, Esq., of Gildersome, near Leeds." Further, in a letter to Mrs. Bilbrough on this matter, he wrote: "The features and expression were regarded as sufficient evidence that he could not have been over 30."

If Yates was correct, the picture must have been painted not later than 1763. One important point noted by Yates is that it is the only portrait in which Priestley is wearing a full-bottomed wig, which, he says, "was the costume of the divinity students, when they left the Academy at Daventry to settle in the ministry"; and, in a note on this statement, he adds: "Dr. Ashworth, under whom Priestley studied at Daventry, once reproved a divinity student, who was beginning to preach, by saying, 'Do you mean, sir, to preach in that pimping wig?'" This would suggest, therefore, that the portrait definitely belongs to the Warrington period, when Priestley had temporarily changed his occupation from minister to tutor in languages. Moreover, a silhouette of Priestley in *Warrington Worthies* (James Kendrick, 1854) shows precisely the same kind of wig.[1] Yates suggests that Priestley probably adopted the wig with curls, in which he appears in later portraits, on the occasion of his marriage (1762).

It is to be noted also that Yates nowhere refers to the portrait as the "Leeds Portrait," a term which has erroneously suggested that it was painted after Priestley settled at Leeds in 1767, and the inference is that it was not so described in 1860 by any of his relatives in Gildersome. Probably the term arose after Yates's time from its association with Gildersome, near Leeds.[2] Or, possibly it

[1] In the Priestley Memorial Volume, Yates says: "During Priestley's residence at Warrington, an artist was employed in making silhouettes of the principal inhabitants. Many of these have been published by Dr. Kendrick in his *Profiles of Warrington Worthies*."

[2] Bolton, (*Scientific Correspondence of Joseph Priestley*, New York, 1892, p. 173), who was unable to say where the portrait then was, described it as "commonly known as the 'Leeds Portrait.'"

arose from the following passage in a letter from Mrs. Bilbrough to Yates: "Well I remember our late relative, Mr. Hudson, relating a little anecdote about the portrait when hanging in the window of the carver and gilder, Leeds. As the Dr. was passing, he stopped to look in at the window, when a woman likewise engaged turned round and exclaimed, 'Why, here's the fellow himsel'." In repeating the story, Yates says: "The picture was once placed in the window of a carver and gilder's shop at Leeds, when Priestley stopped to look at it in passing by. . . ." It is evident from this that Yates did not suppose that the picture was being exhibited on this occasion for the first time. It is reasonable to suggest that Priestley was not

From Kendrick's *Profiles of Warrington Worthies* (1854).

concerned with the portrait, but with the work of the carver and gilder who had been commissioned to regild the frame after his removal from Warrington. Doubtless, the tradesman hoped to attract attention by placing in his window the portrait of the new minister of Mill Hill Chapel.

During the course of our enquiries into this matter, an interesting possibility has suggested itself with regard to the identity of the painter. This, the most pleasing of all Priestley portraits, is obviously the work of no mean artist, though it is difficult to see how Priestley came to sit for any fashionable portrait-painter, since he was neither famous nor wealthy at this period of his life. It is, however, not improbable that the portrait is the work of

Benjamin Wilson, F.R.S. (1721–88). Wilson was the son of Major Wilson of Mill Hill, Leeds, and besides being the author of a treatise on electricity he was one of the best-known portrait-painters of his time. Some of his work was done in Ireland, some in Leeds, but most in London, where he painted, among many of his eminent contemporaries, Benjamin Franklin, Martin Folkes, Lord Chesterfield, David Garrick, and Clive. A common interest in electricity and the circumstances of their Yorkshire origin may well have brought them together during Priestley's periodic visits to London, or it may be that the portrait was painted at Leeds while Priestley and Wilson were both on vacation visits to their native town. On the other hand, a tradition persists in the owner's family that the portrait was painted by Rhodes. We are informed from the National Portrait Gallery that, although definite information is scanty, there appears to have been a family of that name working in Leeds and Sheffield in the early part of last century, and it is supposed that there was a painter of that name and district who died about 1790. There is no further information about him, however, and he remains almost hypothetical.

For much of the information relating to the history of the portrait we gladly acknowledge here our great indebtedness to Mr. Harold Knott, M.A , of Withington, Manchester, with whom we became acquainted through the generous assistance of Professor Glass of Rawdon, Leeds.

As already announced (*Nature*, 1933, **132**, 643), the owner has agreed to confidential notification being made to the Secretaries of the Royal Society and to the Trustees of the National Portrait Gallery of the fact that the portrait is in her possession.

RECENT ADVANCES IN SCIENCE

PURE MATHEMATICS. By E. Maitland Wright, M.A., D.Phil., Christ Church, Oxford.

Algebraic Equations.—In a paper by Schur (*Sitzungsberichte der Preussischen Akademie der Wissenschaften*, 1933, Heft 7–10, 403–28), certain results are found as to the number of real roots of an algebraic equation. Let us take as the typical equation

$$(1) \qquad a_0 + a_1x + \ldots + a_nx^n = 0 \quad (a_0, \quad a_n = 0),$$

where $a_0, a_1, \ldots a_n$ are real or complex, and write

$$P = \frac{1}{\sqrt{|a_0a_n|}}(|a_0| + |a_1| + \ldots + |a_n|).$$

Let r be the number of real roots of (1). Schur first quotes a result of Schmidt's, proved by the use of function theory, that

$$> \exp\left(\frac{r^2}{cn}\right),$$

that is

$$r^2 < cn \log P,$$

where c is a constant independent of n and $a_0, a_1, \ldots a_n$. Schur himself, using only algebraic methods, proves that

$$r^2 - 2r < 4n \log P,$$

and that, when $n > 6$, then

$$(2) \qquad r^2 < 4n \log P.$$

In the opposite direction, if a is a positive constant less than 4, we can find an equation of degree as high as we please such that

$$r^2 > an \log P,$$

so that in (2) we cannot replace 4 by any smaller constant.

Again, let

$$Q = \frac{1}{|a_0a_n|}(|a_0|^2 + |a_1|^2 + \ldots + |a_n|^2).$$

Then $Q \leq P^2 \leq (n + 1)Q$. Let us suppose that (1) has p positive and q negative real roots. Then

$$p^2 + q^2 - |p - q| \leq n \log (\tfrac{1}{2}Q),$$

or

$$p^2 + q^2 - p - q \leq n \log (\tfrac{1}{2}Q),$$

according as n-p-q is odd or even. Also,

$$r^2 - 2r \leq 2n \log (\tfrac{1}{2}Q),$$

and for $n > 6$

$$r^2 < 2n \log Q.$$

Finally, there is no constant $a < 2$ such that

$$r^2 < an \log Q$$

for all equations of sufficiently high degree.

THEORY OF NUMBERS.—Fermat's well-known "last theorem," in reality only a hypothesis, asserts that there is no solution of the equation

$$u^n + v^n = w^n \qquad (n > 2)$$

in rational integers. The impossibility of such a solution has been proved for all n with an odd prime factor less than 100 and for all n divisible by 4. H. Kapferer (*Sitzungsberichte der Heidelberg Akademie der Wissenschaften*, **2**, 1933, 32–7) shows that the existence of a solution of

$$u^n + v^n = w^n \qquad (n \geq 2)$$

in rational integers implies the existence of a solution in rational integers of the equation

$$z^3 - y^2 = 3^3.2^{2n-2}x^{2n}$$

and conversely. Hence Fermat's hypothesis is equivalent to the following:

"The equation

$$z^3 - y^2 = 3^3.2^{2n-2}x^{2n} \qquad (n > 2)$$

has no solutions in rational integers." This certainly appears a less difficult problem to deal with, for n now appears in only one of the terms of the equation and not in all three.

An interesting problem is that of the number of solutions, say N, of

$$f(x,y) \equiv 0 \ (\text{mod}\ p),$$

where $f(x,y)$ is a polynomial in x and y with integral coefficients, p is a prime number, and congruent solutions are to be regarded as equivalent. For example, it is known that $N = p$ for

$$x^3 + y^3 + 1 \equiv 0 \ (\text{mod}\ p)$$

when $p \equiv 2$ (mod 3), and, if $p \equiv 1$ (mod 3), then

$$N = p + O(p^{\frac{1}{2}}).$$

A precise result for more general cubic functions was found recently by Davenport: the number of solutions of the congruence

$$y^2 = (x-a)(x-b)(x-c) \quad (\text{mod}\ p)$$

is

$$N = p + O(p^{\frac{3}{4}}).$$

Mordell (*Mathematische Zeitschrift*, 37, 1933, 193–209) considers the number of solutions of

$$y^m \equiv a_1x^n + a_2x^{n-1} + \ldots + a_{n-1} \pmod{p},$$

or say

$$y^m \equiv f(x) \pmod{p}.$$

When p is large, he shows that

$$N = p + O(p^{\phi(m,n)}),$$

where firstly

$$\phi(2,3) = \phi(2,4) = \tfrac{2}{3},$$

provided $f(x)$ is not congruent to an algebraic square, that is, the case

$$f(x) \equiv b(b_1x^2 + b_2x + b_3)^2$$

is excluded. Next

$$\phi(3,3) = \tfrac{1}{2}$$

provided the case

$$f(x) = b(b_1x + b_2)^3$$

is excluded. For any fixed $m > 3$

$$\phi(m,3) = \tfrac{3}{4};$$

also, provided $f(x)$ is not congruent to an algebraic square

$$\phi(2,5) = \phi(2,6) = \tfrac{7}{8}; \quad \phi(4,4) = \tfrac{5}{6}.$$

THEORY OF FUNCTIONS.—A function is called integer-valued (*ganzwertig*) when it takes integral values for all integral values of the variable. Such functions have been widely studied. In the current volume of the *Rec. math. Moscou*, A. Gelfond studies a different type of integer-valued function, namely those which take integral values at the points

$$1, \beta, \beta^2, \ldots$$

where β is an integer greater than 1. If $g(z)$ is such a function and if

$$g(z) = 0\left(e^{\frac{\log^2|z|}{4\log\beta}}|z|^{-\frac{1}{2}}\right), \tag{3}$$

then $g(z)$ is a polynomial. Writing

$$g(z) = \sum_{n=0}^{n=m} A_n(z-\beta)(z-\beta^2)\ldots(z-\beta^n) + R_m(z),$$

he shows that $R_m(z) \to 0$ for every z as $m \to \infty$. Also if

$$B_m = A_m(\beta - 1)(\beta^2 - 1)\ldots(\beta^m - 1)\beta^{\frac{1}{2}m(m+1)},$$

he shows that B_m is a whole number and that $B_m \to 0$ as $m \to \infty$. Then, after some fixed m, $B_m = 0$. Hence $A_m = 0$ and $g(z)$ is a polynomial. Gelfond also shows that the theorem is no longer true if the bound in (3) is increased.

ASTRONOMY. By R. W. Wrigley, M.A., Royal Observatory, Edinburgh.

Instrumental Development.—The excellent results obtained with the large reflecting telescopes of the Mount Wilson Observatory have encouraged the construction during recent years of instruments of this type, often of considerable size. Their mountings show great improvements over those of their predecessors, but otherwise their features are but little changed Indeed, except for the substitution of silver on glass for speculum metal, an innovation dating from 1856, the reflecting telescope remains very much as Newton left it Even in the matter of size progress has been relatively slow, and there is still but one instrument which exceeds in aperture Lord Rosse's giant reflector constructed over eighty years ago.

There are, however, signs that this lull will shortly be succeeded by an era of rapid progress. The glass mirror is difficult to cast in very large sizes, and it is liable to distortion under the influence of temperature changes, while the silver film, in addition to tarnishing easily, is deficient in reflecting power in the ultra-violet region even when new G. W. Ritchey's experiments with large mirrors built up from glass plates cemented into a cellular structure, and the results obtained by using fused quartz instead of glass in connection with the preliminary work on the projected 200-inch telescope, all seem likely to result in the production of mirrors considerably bigger and less susceptible to temperature changes. Further, a method of depositing metallic films by evaporation in a high vacuum has been recently applied with success to mirrors of considerable size, and the perishable silver film will probably soon be superseded by stable films of chromium or aluminium, which both exhibit a higher reflecting power in the ultra-violet. An apparatus and technique for depositing these films is described in the *Astrophysical Journal*, **77**, No. 5, by R. C. Williams and G. B. Sabine of Cornell University, and success has so far been obtained with mirrors up to 22 inches in diameter. The essential parts of the apparatus are a steel bed-plate, a glass bell-jar, and a high vacuum pumping system, and it has been found that bright films cannot be obtained if the air pressure exceeds 10^{-4} mm. of mercury. The metal to be deposited is distilled on to the glass surface by evaporation from a heated tungsten filament. When chromium is thus applied it exhibits no tarnish whatsoever on prolonged exposure even to atmospheres of ozone, hydrogen sulphide and sulphur dioxide, but, once deposited, it cannot be removed without damage to the optical surface of the glass. This difficulty can,

however, be avoided if a thin layer of gold is first evaporated upon the surface, and the two removed together. Aluminium films do not have the mechanical durability of chromium, and can be removed by hydrochloric acid, but they resist tarnish remarkably well. Owing to its low melting point aluminium is readily evaporated, and, as it has a high reflectivity both in the visible and in the near ultra-violet regions of the spectrum it seems peculiarly suited for use in astronomical reflectors. A remarkable demonstration of the thinness and homogeneity of these metallic films was made by coating glass diffraction gratings with both aluminium and chromium. In neither case was the quality of the spectrum impaired, while a great increase in intensity in the visible and near ultra-violet was noted

Attention is also being directed to the optics of the reflector with a view to increasing its field. For images close to the axis the paraboloidal mirror which is the feature of the Newtonian telescope is an almost perfect instrument, and when a reflector is required simply to feed a slit spectrograph a mirror of this form, coupled either with the flat of the Newtonian or with the hyperboloidal secondary of the Cassegrain, is scarcely capable of improvement. But the useful field in either case is very small owing to coma, and, since this increases as the square of the relative aperture, the very rapid reflectors of aperture $f/3$ have fields of only a few minutes of arc in diameter. As long as the principal mirror remains paraboloidal the addition of a curved secondary mirror is of little assistance towards increasing the field, but there is a possibility of achieving this end by specially figuring both the main and the secondary mirrors. The subject was fully investigated many years ago by Schwarzschild, who showed in particular how a modified Gregorian reflector could be constructed with a relative aperture of the order of $f/2$ and yet have a large flat field of about two degrees in diameter. A telescope of this type has actually been completed and is now being installed at the Observatory of the University of Indiana. A corresponding modification of the Cassegrain telescope has recently been investigated by H. Chrétien. This, however, has less striking advantages, for the field is so strongly curved that curved plates and a special measuring machine must be used. In addition, if the secondary mirror is not to obstruct too much of the light, the relative aperture must be kept of the order of $f/8$, and the field becomes comparatively restricted. A 40-inch telescope of this type working at $f/6{\cdot}8$ is now being constructed for the Naval Observatory, Washington, by G. W. Ritchey.

Greater possibilities are afforded when lenses as well as mirrors

are introduced. Some years ago (*Phil. Trans.* **213**) R. A. Sampson proposed a modified Cassegrain arrangement in which the convex mirror was replaced by a weak convexo-concave lens silvered at the back, while about two-thirds of the way between this and the surface of the great mirror was placed a pair of lenses of nearly equal but opposite focal lengths, the first being double concave and the second nearly plano-convex. The three lenses were to be made of the same glass in order to secure achromatism, and, by choosing appropriate curvatures, strictly circular images could be obtained at a distance of one degree from the centre of the field.

In the *Astrophysical Journal*, **77**, No. 4, F. E. Ross describes a "correcting lens of zero power" designed for eliminating the coma of a paraboloidal mirror, which has been applied to the 60-inch telescope at Mount Wilson. It is of 8-inch aperture, is placed 15 inches from the Newtonian focus, and is only approximately of zero power as it increases the focal length of the mirror by 4·4 inches. This corrector lens removes the coma at the expense of the astigmatism, but, as the latter only becomes noticeable at about 55 minutes from the axis, the useful field is very much increased. A similar lens will probably be constructed for use with the projected 200-inch telescope. As the coma increases linearly from the centre of the field and as the square of the aperture ratio of the mirror, it might be a very serious matter seeing that the proposed aperture ratio is 3·3.

The most striking advance in the design of reflectors is, however, due to B. Schmidt of Hamburg, and is described in *Mitteilungen der Hamburger Sternwarte in Bergedorf*, **7**, No. 36. The usual paraboloidal mirror is replaced by a spherical one, which can be figured cheaply to any desired curvature. Hitherto the mirror itself has always been used as the entrance stop, but Schmidt places the latter near the centre of curvature, and by this simple step practically eliminates coma, astigmatism and distortion at a stroke. Except for the slightly elliptical shape which the entrance stop assumes to rays off the instrumental axis, the images are formed under similar conditions throughout the whole field. There is therefore only spherical aberration remaining, and this is corrected by placing at the entrance stop a single lens of so low a power that its chromatic aberrations are negligible. The corrected field obtained in this way is larger than the entrance stop itself, and naturally cannot all be used without obstructing the light, but by means of a thin strip of film Schmidt shows that images of objects eight degrees from the axis can hardly be distinguished from those actually on the axis, even with a relative aperture of $f/1{\cdot}75$. The

field is strongly curved (it has double the curvature of the large mirror), but it is found that films can be pressed to its shape without damage. The Hamburg Observatory has distributed prints from photographs taken with a Schmidt telescope of 36 cm. aperture working at $f/1{\cdot}75$, covering a field eight degrees in diameter, and these substantiate the claims of the designer.

As the correcting lens must be equal in diameter to the full aperture of the telescope, it seems that the size of this type of instrument is necessarily limited. It is however so much more rapid than a triplet lens of the same diameter, and so much cheaper in its construction, that it seems certain that it will be widely used in the future in as large sizes as possible.

THE EXPANDING UNIVERSE.—The red shift which has been observed in the spectral lines of distant nebulæ is generally accepted as evidence of enormous recessional velocities, but actually it is a phenomenon which admits of a large number of cosmogonic interpretations. All that we really learn from the observations is that light which comes from great distances and which has therefore been a long time on the way has become reddened. It is of course possible that the effect may simply be due to a loss of energy of the light photon with age, and the observed shift of the spectral lines could be produced by a loss of only one per cent. in a journey extending over 17,000,000 years. As yet, however, no hypothesis sufficient to account for such a loss has been forthcoming.

In *Nature*, **132**, 406, Miss Janet Clark of the Johns Hopkins University points out that even if the red shift is actually due to real nebular velocities this does not necessarily imply a universe ever expanding at an ever-increasing rate. Assuming that the speed of recession has definitely been found to increase with the distance of each nebula at a rate of 550 km. per sec. for each megaparsec, the deduction of a uniform expansion of the universe still rests on the further assumption, without any evidence in its support, that the distant nebulæ have been moving with similar velocities for at least 150,000,000 years. All we really know is that 150,000,000 years ago a distant nebula was receding at a rate of about 25,000 km. per sec., 50,000,000 years ago a nearer one was receding at about 8,500 km. per sec., 3,000,000 years ago one still nearer was receding at about 550 km. per sec., while some of our nearest neighbours appear to be actually moving towards us. The observed distribution of nebular velocities may therefore depend not on distance but on time. It may reasonably be argued that these velocities have been steadily decreasing during the last 150,000,000 years, and have been brought to zero during the last million, thus inferring a periodic

universe in which an epoch of decreasing expansion has just passed and one of condensation is about to begin. A critical reply by Sir Arthur Eddington appears in the same number of *Nature.* He admits the contention of Miss Clark that from the observational evidence alone it is impossible to decide whether the universe is expanding or about to contract, but points out that the latter alternative would necessarily postulate some attractive force, much too large to be due purely to the ordinary gravitation of the system, and which cannot be accounted for by any reasonable theory. The expansion theory is the only one out of the many possible interpretations of the observed nebular motions which can find any support from pure physical theory, and it is in fact an unescapable consequence of such theory Eddington therefore prefers to regard the recession of the nebulæ as simply in accordance with this theory, and as providing a possible clue to the mystery of the structure of protons and electrons. He is determined to assume that the theory of the expanding universe provides the correct explanation of the observations until the contrary can be definitely proved.

Hitherto one of the great difficulties in accepting this theory has been the comparatively limited time scale which it involves, for apparently the whole life of the universe is less than the time necessary for the evolution of a star. This paradox, that the stars seem older than the universe, is dealt with by W. De Sitter in *Monthly Notices*, R.A.S., **93**, 628. In his book *Kosmos*, published last year, he was prepared to accept this anomaly, and to consider the universe as a " hypothesis like the atom, with freedom to have properties and to do things which would be contradictory and impossible for a finite material structure." He was willing to regard the change of radius of the universe and the evolution of the stars as two different processes, going on side by side but with no apparent connection. In this later paper, however, he adopts the view that the " beginning of the universe " was merely a time when one of the quantities " y " connected with it passed through its minimum value. The original conception of a universe shrinking to a mathematical point at one particular moment of time must therefore be replaced by that of a near approach of all the galaxies to one another during a comparatively short interval. According to this view the " beginning of the universe " becomes only a transitory episode in its history, no more remarkable than the passage of a planet or comet through its perihelion. There is then nothing paradoxical in demanding a longer time scale for the lives of individual stars. The near approach and mutual penetration of the galaxies which is

represented by the minimum value of "y" apparently took place between 10^9 and 10^{10} years ago, and de Sitter notes that the age of our earth, computed from the evidence of minerals in its crust, is probably of the same order. The origin of the solar system of planets, including the earth, is ascribed by modern theory to a near approach of another star to our sun, a phenomenon which, in our galactic system as at present constituted, would be so rare as to make it almost unique. But at an epoch when the galaxies were interpenetrated the chance of such an encounter would be greatly increased, and our system need not therefore be regarded as a freak of nature. De Sitter suggests that the earth was therefore born at the "beginning of the universe," but that the sun and other stars are much older, dating from a time anterior to that when the universe assumed its present configuration But concerning the real "beginning" we are of course no wiser.

PHYSICS. By L. F Bates, Ph.D., D.Sc, F.Inst.P., University College, London.

The Magnetic Rotation of Gases and Vapours.—Most of us are painfully aware that experiments in physics on an engineering scale are becoming more and more common, and one of the latest is described in a paper by M. P. Gabiano (*Ann. de Phys.*, XX, 68, 1933), who has examined the magnetic rotation of the plane of polarisation of light by gases and vapours

As is well known, magnetic rotation was first discovered by Faraday in 1846. Faraday used a special glass to show the phenomenon, but we now know that it is exhibited by any transparent substance. A beam of plane polarised light is passed through an isotropic transparent body so that the rays of light are parallel to the lines of force of a magnetic field in which it is placed. On establishing the field the plane of polarisation is turned through an angle α which is proportional to $\int$ H.dl, the difference in magnetic potential between the two ends of the body.

Faraday placed his glass between the poles of an electromagnet. Later, Verdet (1856) placed substances along the axis of a solenoid and measured the constant Λ, which bears his name, in the expression $\alpha = \Lambda . \int$ H.dl. Verdet showed that the majority of substances exhibited positive magnetic rotation, *i.e.* a rotation in the same direction as the magnetising current, although a few substances, such as iron salts and titanium chloride exhibited a rotation in the opposite direction.

In 1878, H. Becquerel in Paris and Kundt and Röntgen in Strasbourg proved that the phenomenon was exhibited by gases. Becquerel used a long solenoid and produced a difference of magnetic potential of the order of 10^4 c.g.s. units. This was insufficient to produce a measurable rotation with a single passage of the beam of light through the gas at atmospheric pressure, and the light was reflected back and forth through the body nine times, so that the effective difference of potential was increased ten times. However, this apparently simple device for increasing the sensitivity involves considerable difficulty in practice because of loss of light, etc.

Kundt and Röntgen, on the other hand, used a difference of magnetic potential of the order of 9×10^4 c.g.s. units and obtained measurable angles of rotation by using gases under high pressure. To get rid of the double refraction produced by high pressures unequally distributed on the glass portions of their apparatus, they enclosed their polariser and analyser within the tube containing the gas. Actually, they had no nicol prisms, and they used tourmalines, making their observations with white light.

Siertsema (*Versl. Amsterdam Acad.*, **5**, 131, 1897; *Arch. Néerlandaises des Sciences*, **2**, 291, 1899) considerably improved the latter method. He used nicol prisms and a spectrometer to examine the magnetic rotation of particular wavelengths, and produced a difference of magnetic potential of 3×10^5 c.g.s. units by means of a solenoid a little over two and a half metres long. However, none of the above workers actually investigated the rotation of vapours as distinct from permanent gases, and Bichat (1878) appears to be the only worker to use a vapour, carbon bisulphide. In recent years, of course, much work has been done with sodium vapour, but we are not concerned with it here.

Gabiano's work is more particularly concerned with the magnetic rotation of vapours and with the variation of the specific magnetic rotatory power, *i.e.* the Verdet constant of a substance divided by its density, as the substance passes from the liquid to the gaseous state, although he has also examined some of the permanent gases to supplement existing data.

As he desired to produce a measurable rotation with a single transmission of a beam of light through a gas at a low pressure, he used a solenoid six metres long. This was wound with six bobbins in series; each was one metre long and weighed about 75 kg. The total number of turns was 21,276, and the normal working current was 24 amperes. A brass tube 35 mm. in diameter, 1 mm. thick and over 6 m. long, contained the gas, and was sur-

rounded by a second brass tube, 55 mm. in diameter, in which water circulated. There was nothing unusual about the optical arrangements beyond the careful mounting of the glass end plates; measurements were usually made with the mercury yellow line. To ensure accuracy, no values of the density, etc. of the substances used were taken from tables—all were determined for the actual specimens used in the rotation experiments.

A considerable number of valuable numerical results have been obtained with this apparatus. In addition it has been shown that the specific rotatory power of a vapour divided by the specific rotatory power of its liquid is equal to $\frac{9n}{(n^2+2)^2}$, where n is the index of refraction of the liquid. This relation holds very satisfactorily for substances such as pentane, hexane, methyl iodide, benzene, carbon bisulphide and sulphur dioxide. Oxygen, which is paramagnetic, appears at present to form an exception, and is being investigated separately. The relation is not empiric, it is definitely suggested by the molecular theory of magnetic rotation as given by Mallemann (*Journ. de Phys.*, **7**, 295, 1926). Moreover, it forms a definite proof of the correctness of adopting the simple Lorentz expression for the internal electrical field inside a substance, on which Mallemann's theory is based. This simple expression contains the $\frac{4\pi}{3}$ so frequently encountered by physicists and chemists in formulæ for molecular polarisation and refraction; consequently, this proof is of some importance. For a liquid Mallemann's theory gives $\frac{\Lambda \cdot n}{\rho(n^2+2)^2}$ = constant, from which the above relation may easily be deduced.

From a comparison of molecular magnetic rotatory powers the values of the specific atomic rotatory powers have been deduced. The values thus obtained differ considerably from those previously calculated by other workers. By their use it is now possible to calculate fairly approximately the magnetic rotatory power of an organic compound either in the liquid or gaseous state.

The Positive Electron.—At the British Association Meeting at Leicester, P. M. S. Blackett summarised the present position of our knowledge concerning the positive electron. He paid particular attention to experiments in which γ-rays are allowed to fall upon heavy elements, for these experiments are relatively simple to examine. It is found that if a narrow beam of γ-rays from Thorium C′, which have an energy of $2{\cdot}65 \times 10^6$ electron volts, is allowed to impinge on a sheet of lead, positive and negative electrons are

emitted, the positive electrons comprising some 7 per cent. of the total emission. If, however, the lead is replaced by aluminium, practically no positive electrons are liberated.

Now, a more penetrating beam of γ-rays may be produced by the action of a beam of α-rays upon beryllium. Thus, if a beam of α-rays impinges upon a beryllium target, γ-rays having an energy of 5×10^6 electron volts emerge. When these fall upon a sheet of lead, the positive electrons emitted comprise some 35 per cent. of the total electron emission. With these rays some 10 per cent. is emitted from a sheet of aluminium, and 40 per cent. from an uranium screen. The energy of the positive electrons is less than that of the negative; in the case of the lead sheet exposed to $2{\cdot}65 \times 10^6$ electron volt γ-rays, the positive electrons have maximum energies of about $1{\cdot}7 \times 10^6$ electron volts, instead of the $2{\cdot}65 \times 10^6$ maximum of the negative electrons.

The production of the two kinds of electrons may be attributed to a photo-electric effect in the atom exposed to γ-radiation. Since their numbers and energies are comparable, the method of production of both electrons must be the same. It is unlikely that the positive electrons come from the nucleus, for the probability of the collision of a quantum of γ-radiation with a nucleus is far too small to account for the large number of positive electrons observed.

Blackett therefore suggests that the effect is an extranuclear one, which spectrographic evidence definitely requires to occur inside the K. electron level in the atom. He suggests that positive and negative electrons are born as twins, a view supported by the experiments with uranium mentioned above, and by a large number of his expansion chamber photographs. In order that the electrical charge in an atom may be conserved, the charge on a positive electron must be numerically equal to the charge on a negative.

Direct experiment has so far shown that the mass of the positive electron is equal to that of the negative, within some 50 or 100 per cent.; calculation allows us to make practically certain that they are equal. Thus, if we write $(m_+ + m_-)\cdot c^2 = 2m\cdot c^2$ and substitute the accepted values of m and c, we obtain an energy of $1{\cdot}02 \times 10^6$ electron volts. This means that the creation of one positive and one negative electron requires approximately $1{\cdot}02 \times 10^6$ electron volts. Consequently a positive electron can have a maximum energy when expelled by a $2{\cdot}65 \times 10^6$ γ-ray of $(2{\cdot}65 - 1{\cdot}02) \times 10^6 = 1{\cdot}63 \times 10^6$ electron volts; the direct experimental value is $1{\cdot}7 \times 10^6$. This clearly allows us to say that $m_+ = m_- \pm 10\%$.

Now, it is generally postulated that a negative electron possesses

a quantum spin of one-half a quantum unit. In order that angular momentum may be conserved, the positive electron must have an equal but opposite spin. It will be realised that we know nothing of any embryo or nascent state of the positive and negative electron twin, and presumably its creation is only possible by the annihilation of radiation. It is of interest, to the writer of this article at any rate, that at birth the twin forms a magnetic particle of two Bohr units

Blackett showed that the above conception of the emission of positive electrons provides another picture of the way in which γ-rays may lose energy, and probably accounts for the anomalous absorption of γ-rays recorded by Grey and Tarrant without resource to intranuclear phenomena. He dealt also with a difficulty presented by an experiment of Curie and Joliot When a beam of α-rays falls on a beryllium or aluminium target, positive electrons of 2×10^6 electron volts energy are produced, but very few negative electrons are emitted. Blackett suggests that in this case the nucleus is stimulated by an α-ray and a γ-ray is emitted, but the latter is internally converted with the production of positive and negative electrons, the positive emerging with large kinetic energy and the negative with little, so that only the positive is effectively recorded.

Finally, why has the positive electron so long eluded detection? The reason is that it so readily combines with a negative electron to produce γ-radiation. Or, in the words of Lord Rutherford, " the positive electron has come to stay, but its stay is a short one."

Some very beautiful photographs of positive electron tracks from cosmic rays are reproduced in a paper by Anderson (*Phys. Rev.*, **44**, 406, 1933).

Experiments on Magne-Crystallic Action.—Two papers which are of considerable importance to chemists and physicists have recently appeared on the subject of the magnetic behaviour of crystalline substances. In the first of these papers (*Phil. Trans. Roy. Soc.*, **231**, 235, 1933), K. S. Krishnan, B. C. Guha and S. Banerjee deal with diamagnetic crystals. From investigations of the double refraction of liquids it is known that in general the molecules of diamagnetic substances are magnetically anisotropic. Consequently, when such molecules are arranged in a regular manner in a crystal, their orientations must produce differences in magnetic susceptibility in different directions, and Krishnan suggested that the measurement of the resulting magnetic anisotropy would provide important information concerning molecular orientations. Actually, the authors state that in certain cases the mole-

cular orientations in the crystal can be more easily and accurately determined by the method of magnetic analysis than by X-ray methods.

The magnetic method of analysis possesses the great advantage over optical methods in that a knowledge of the relative positions of the molecules in the crystal is not needed. Various methods of measuring the magnetic anisotropy may be employed. Thus, Voigt and Kinoshita first located the principal magnetic axes of a crystal and determined the absolute susceptibilities along them; this method, however, does not give the differences in susceptibility along the different axes with sufficient accuracy.

Again, a diamagnetic crystal may be suspended in a magnetic field from the end of a thin quartz fibre. In general, a couple due to the asymmetry of shape and the non-uniformity of the field, and a couple due to the magnetic anisotropy of the crystal will act upon it. The second couple tends to set the magnetic axis of greater (algebraic) susceptibility along the field. The first couple may be caused to vanish by using a sphere of the material under investigation.

However, Krishnan and his collaborators show that with a crystal of any shape this first couple may be almost completely avoided if the field is really homogeneous, *i.e.* of the type which obtains between large flat pole-pieces. The crystal is set with one magnetic axis parallel to the field and may then be caused to oscillate under the influence of the second couple and the torsion constant of the fibre.

Let T_1 and T_0 be the periods of oscillation when the crystal is in a field of strength H and in zero field respectively. Let c be the torsion constant of the fibre, m the mass of the crystal, M its molecular weight and χ_1 and χ_2 the maximum and minimum gram-molecular susceptibilities of the crystal in the plane of oscillation. Then

$$\chi_1 - \chi_2 = \frac{T_0^2 - T_1^2}{T_1^2} \cdot \frac{c}{H^2} \cdot \frac{M}{m}.$$

Consequently, $\chi_1 - \chi_2$ may be obtained with considerable accuracy. The main experimental difficulty is, of course, the mounting of the crystal with one axis parallel to a short length of glass fibre which is attached to the lower end of the quartz suspension.

In this way, however, the inorganic crystals quartz, calcite, aragonite, strontianite, witherite, sodium nitrate, potassium nitrate, potassium chlorate, barite, celestite, anhydrite, gypsum and sulphur were examined. The most striking result was that the nitrates and carbonates showed a large magnetic anisotropy, whilst the

sulphates were more or less magnetically isotropic. This is presumably due to the anisotropy of the NO_3^- and CO_3^- ions and to the symmetrical arrangement of the oxygen atoms in the SO_4^{--}ion.

In the case of the organic crystals investigated it was necessary to measure the absolute susceptibility of the crystals to supplement the meagre data previously available. For this purpose the method of Rabi (*Phys. Rev.*, **29**, 174, 1927) was used with some modifications. As the differences in susceptibility along the several axes were known from the above experiments, it was only necessary to measure the absolute susceptibility along one axis.

The crystal was therefore mounted at the end of a thin quartz fibre, with the axis along which the susceptibility was to be measured parallel to the direction of a non-uniform magnetic field. In general, the field causes a lateral displacement of the crystal. Such displacement, however, does not occur when the crystal is surrounded by a solution whose volume susceptibility is the same as that of the crystal in the direction of the field. Solutions of manganese chloride of appropriate concentration were therefore used, their susceptibilities being found by a modified Quincke method.

The organic crystals examined were naphthalene, anthracene, β-naphthol, acenaphthene, diphenyl, dibenzyl, benzophenone, benzil, azobenzene, hydrazobenzene and salol. In most cases the mean of the three observed principal susceptibilities agreed satisfactorily with the values calculated from Pascal's rules, although azobenzene and hydrazobenzene gave experimental mean values much lower than the calculated values. The magnetic constants for benzene were calculated from its Cotton–Mouton constant and the depolarisation factor of its light-scattering, and it is very striking that as one proceeds from benzene to naphthalene and from naphthalene to anthracene, the numerical increases in diamagnetic susceptibility are confined almost entirely to the direction normal to the plane of the benzene rings.

With the help of data on magnetic double refraction and light-scattering it is in some cases possible to correlate the principal magnetic constants of the crystal with those of the individual molecules of which it consists. Thus in the cases of diphenyl and dibenzyl it is possible to determine the exact orientations of the molecules in the unit cell; these have recently been confirmed by Dhar. In other cases, *e.g.* stilbene, the magnetic data helps in deciding between alternative orientations suggested by X-ray methods.

In the second paper (*Phil. Trans. Roy. Soc.*, **232**, 99, 1933), K. S. Krishnan, N. C. Chakravorty and S. Banerjee describe a

series of experiments on paramagnetic crystals. The binding forces in these crystals are much more prominent than in the case of the diamagnetic crystals in determining the anisotropy. The magnetic anisotropy of paramagnetic crystals is often very pronounced, and the experimental data, previous to the paper under discussion, was meagre and obviously open to question in many cases. Indeed, a very critical survey of the earlier data is given.

The investigations were made by the methods described in the first paper, and a special technique for dealing with crystals of feeble anisotropies was employed. This was particularly necessary in the case of a crystal such as manganese ammonium sulphate, where the difference between the maximum and minimum principal gram molecular susceptibilities is only 11·4, whilst the mean value is 13,830.

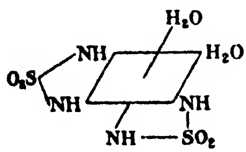
Crystals of nickel salts are also only feebly anisotropic, and give a value of 15·8 Weiss magnetons for the Ni^{++}ion. Salts of iron and of cobalt are strongly anisotropic, and the mean susceptibility depends very much on the nature of the salt. It is interesting to note that low temperature measurements on these crystals have been started, and the results will be awaited with much interest.

GENERAL AND ORGANIC CHEMISTRY. By O. L. Brady, D.Sc., F.I.C., University College, London.

The Atomic Weight of Carbon.—For many years the International Commission for Atomic Weights has accepted the figure 12·0 for the atomic weight of carbon, but the discovery that this element consisted of two isotopes C^{12} and C^{13} suggested that this value was too low unless the C^{13} isotope was present in very small amounts. Woodhead and Whytlaw-Gray (*Journal Chem. Soc.*, 1933, 846) have redetermined the atomic weight of carbon by a direct comparison of the densities of oxygen and carbon monoxide at varying pressures. A fibre suspension silica buoyancy balance was employed (*Proc. Roy. Soc.*, 1931, A. **134**, 7) and the ratio of the pressures at which the two gases had the same density was measured. Many refinements of technique are introduced, for which the original paper should be consulted, and as the result of a considerable number of concordant measurements the authors conclude that 12·011 is a close approximation to the atomic weight of carbon on the chemical scale. This figure is in agreement with the results calculated from Rayleigh's determination of the density of carbon monoxide (*Proc. Roy. Soc.*, 1897, **62**, 204). There are numerous disadvantages in atomic weight determinations involving the manipulation of gases, and a redetermination of the atomic

weight of carbon by other methods is desirable as a check on these results; unfortunately this element presents peculiar difficulties in connection with the determination of the combining ratios between it and any of the standard elements. The authors conclude that if their figure be accepted the proportion of the C^{13} isotope must be as high as 1 per cent., a result in agreement with those obtained by spectrum methods by Jenkins and Ornstein (*Proc. K. Akad. Wetensch., Amsterdam*, 1932, **33**, 1212). It is not clear why the authors place the percentage so high since they point out at the beginning of their paper that the weight of the atom C^{12} reduced to the standard of chemical oxygen may be as high as 12·0023, but the amount of C^{13} isotope in ordinary carbon seems to lie between 0·5 and 1 per cent. If this be the case, the organic chemist is faced with an appalling prospect: hydrogen of mass 2 has now been isolated and although the separation of carbon of mass 13 presents formidable difficulties, we may yet see isolated the ten compounds a mixture of which we now know as methane.

An Optically Active Inorganic Salt.—Although Werner many years ago succeeded in resolving into optical isomerides compounds whose asymmetry was due to the arrangement of groups round a cobalt atom, these all contained carbon in the form of ethylene diamine. Mann (*Journal Chem. Soc.*, 1933, 412) has succeeded in resolving a compound containing no carbon, namely sodium diaquorhodiumdisulphamide $Na[(H_2O)_2Rh(N_2H_2SO_2)_2]$.



(I)

The cis form (I) of this compound possesses molecular asymmetry and has been resolved; crystallisation of *d*-α-phenylethylamine diaquorhodiumdisulphamide and treatment with sodium hydroxide gave the active sodium *d*-diaquorhodiumdisulphamide [M] = + 31. Crystallisation of the *d*-Nor-ψ-ephedrine salt gave sodium *l*-diaquorhodiumdisulphamide [M] = − 33·5°.

The Constitution of Ascorbic Acid.—Whether or no *l*-ascorbic acid (originally called hexuronic acid by its discoverer, Szent-Györyi) is pure crystalline vitamin C will soon be decided. All preparations of this compound, which is widely distributed in plants and animals, from natural sources have strong antiscorbutic properties and now that the compound has been synthesised free from

any possible antiscorbutic impurities, the results of the physiological tests will be awaited with great interest.

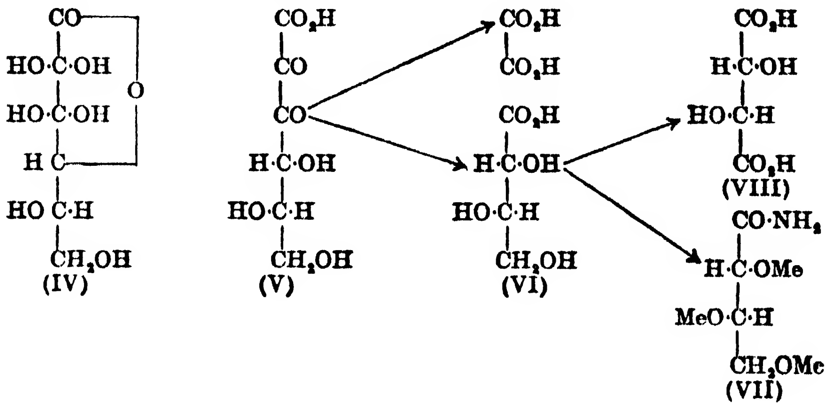
Herbert, Hirst, Percival, Reynolds and Smith (*Journal Chem. Soc.*, 1933, 1270) have published an important paper on the constitution of this compound. *l*-Ascorbic acid has the molecular formula $C_6H_8O_6$, is a weak acid giving salts of the type $C_6H_7O_6M$, and contains a double bond (Karrer, Salomon, Schöpp and Morf, *Helv. Chim. Acta*, 1933, **16**, 181). It is a powerful reducing agent, especially in alkaline solution, it forms a phenylhydrazone and its colour reactions with ferric chloride and with sodium nitroprusside indicate the presence of an enolisable carbonyl group. As it gives no colour reaction with Schiff's reagent, an aldehydic group is not likely to be present and the quantitative production of furfuraldehyde with hydrochloric acid shows that at least five of the six carbon atoms are in an unbranched chain.

From a study of its oxidation products Herbert, Hirst, Percival, Reynolds and Smith have arrived at a satisfactory structure for ascorbic acid. Oxidation with aqueous iodine in acid solution requires two atomic proportions of iodine and two molecular proportions of hydriodic acid are liberated; the action is therefore the addition of two hydroxyl groups to a double bond, it being noteworthy that no oxidation occurs in non-aqueous media. The product is neutral in reaction and behaves as the lactone of a monobasic hydroxy acid; no disintegration of the molecule has occurred since ascorbic acid can be regenerated by reduction. From this it is obvious that there is no free carboxyl group in ascorbic acid and that its acidic properties are due to an activated $-CHOH$ group situated next to a carbonyl group. In its enolic form this combination of groups would be of the type $-C(OH):C(OH)-$ giving on oxidation in the presence of water $-C(OH)_2-C(OH)_2.-$ Dihydroxymaleic acid (II) supplies a close analogy and under the same conditions is oxidised to dihydroxytartaric acid (III) which can be quantitatively reduced to dihydroxymaleic acid again.

$$\begin{array}{ccc} HO\cdot C\cdot CO_2H & \xrightarrow{\text{oxidation}} & (HO)_2\cdot C\cdot CO_2H \\ \| & & | \\ HO\cdot C\cdot CO_2H & \xleftarrow{\text{reduction}} & (HO)_2\cdot C\cdot CO_2H \\ \text{(II)} & & \text{(III)} \end{array}$$

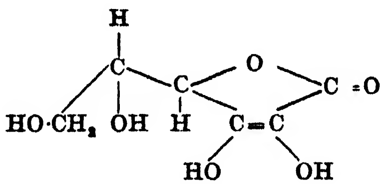
With alkaline sodium hypoiodite this first oxidation product of ascorbic acid is oxidised quantitatively to oxalic acid and a trihydroxybutyric acid (VI) which has been shown to be *l*-threonic acid by conversion to the crystalline trimethyl-*l*-threonamide (VII) and by oxidation with nitric acid to *d*-tartaric acid (VIII). Ascorbic

acid is therefore a derivative of *l*-gulose and the iodine oxidation product (IV) must be capable of acting as 2 : 3-diketo-*l*-gulonic acid (V), being in fact a lactone of this acid with in all probability the keto groups hydrated.



The compound (IV) was not isolated so the hydration of the keto groups could not be established by analysis, but arguments are adduced in favour of this view. The position of the lactone bridge has been settled by the classical methods from the study of the methylation product of ascorbic acid.

From the above considerations the structure (IX) has been assigned to *l*-ascorbic acid and the authors show that this is consistent



(IX)

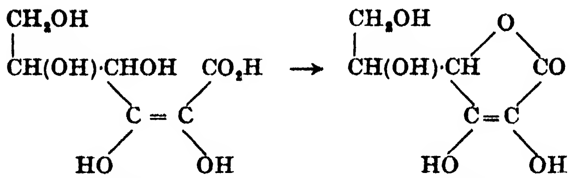
with the very considerable amount of information available on the chemical and physical properties of the compound.

This work has been followed by the synthesis of *l*-ascorbic acid by a team at the University of Birmingham (Ault, Baird, Carrington, Haworth, Herbert, Hirst, Percival, Smith, and Stacey, *Journal Chem. Soc.*, 1933, 1419). *l*-Xylosone (X) was converted to its cyanhydrin (XI) by treatment in aqueous solution with potassium cyanide and calcium chloride in an atmosphere of nitrogen. This compound underwent spontaneous hydrolysis to *l*-ψ-ascorbic acid (XII) which differed from *l*-ascorbic acid in its absorption spectrum and in giving a different osazone after oxidation ; when, however,

it was digested with 8 per cent. hydrochloric acid for 26 hours at 45–50° it was converted to *l*-ascorbic acid (IX) which, after a difficult process of isolation, was obtained finely crystalline and found to be identical in every respect with the natural product.

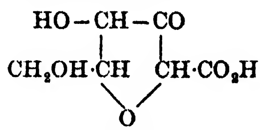
$$CH_2(OH)\cdot CH(OH)\cdot CH(OH)\cdot CO\cdot CHO \rightarrow$$
(X)

$$CH_2(OH)\cdot CH(OH)\cdot CH(OH)\cdot CO\cdot CH(OH)\cdot CN$$
(XI)



(XII) (IX)

Starting from *d*-xylosone, *d*-ascorbic acid has been synthesised in an analogous manner. Previously, however, Reichstein, Grüssner and Oppenauer (*Helv. Chim. Acta*, 1933, **16**, 561) had described the synthesis of this compound from the same source and considered that their work supported a formula for ascorbic acid (XIII) put forward by Michael (*Nature*, 1933, **131**, 274).



(XIII)

They assumed that no opening of the furane ring occurred during the synthesis, but the work of Herbert, Hirst, Percival, Reynolds and Smith and of Ault, Baird, Carrington, Haworth, Herbert, Hirst, Percival, Smith and Stacey have rendered this assumption untenable and this structure (XIII) has been abandoned by its originator and by Reichstein.

Though the actual synthesis was short and yields of 70 per cent. were obtained, the preparation of sufficient quantities of *d*- and *l*-xylosone involved the labours of a team of workers over many months and the chief losses of material occurred in these stages.

The Addition of Hydroxyl Groups at the Double Bond.—The employment of potassium permanganate to bring about this reaction has many objections, notably the necessity for its use in aqueous solution and the difficulty in preventing the oxidation going too far. As this addition is of considerable importance, a new reagent described by Prevost (*Compt. Rend.*, 1933, **196**, 1129) should attract attention. He finds that when silver benzoate is

treated with iodine, a complex $AgI(OBz)_2$ is formed, which reacts with unsaturated compounds to give glycol dibenzoates, which can be hydrolysed to glycols.

$$RCH : CH_2 + AgI(OBz)_2 = RCHOBz{\cdot}CH_2OBz + AgI.$$

It is not necessary to prepare the iodine-silver benzoate complex as the reaction can be brought about by treating a benzene solution of one gram molecule of the ethylene with two gram-molecules of silver benzoate and two gram atoms of iodine ; in some cases the reaction takes place rapidly in the cold but in others it is necessary to boil for from one to fifty hours.

ORGANOLITHIUM COMPOUNDS.—The convenient preparation of organolithium compounds was described by Ziegler and Colonius (*Annalen*, 1930, **479**, 135). Gilman, Zoellner and Selby (*Journal Amer. Chem. Soc*, 1932, **54**, 1957 ; *ibid.*, 1933, **55**, 1252) have shown that these compounds can be prepared and used in a similar manner to the Grignard reagents. Whilst some halides which react readily with magnesium in ether are comparatively unaffected by lithium, in a number of cases the reverse is the case, the two metals thus supplementing one another The advantage of this in synthetic work will be obvious. Although many of the reactions of organolithium compounds are analogous to those of the Grignard reagents, this is not always the case. Gilman and Van Ess (*ibid.*, 1258) show that under ordinary conditions phenyllithium reacts with carbon dioxide to give a 70 per cent. yield of benzophenone, but by adding the phenyllithium in the form of a spray to solid carbon dioxide, as much as 60 per cent. of benzoic acid can be obtained. With benzoyl chloride, phenyllithium gave no benzophenone, but 42 per cent. of triphenylcarbinol. Further studies by Gilman and Kirby (*ibid.*, 1265) show that phenyl and methyl lithium react normally with *p*-dimethylaminobenzonitrile, which is unattacked by the Grignard reagent and whereas phenyl magnesium bromide with benzophenone anil $(C_6H_5)_2C = NC_6H_5$ gives *o*-phenylbenzohydrylaniline $(C_6H_5{\cdot}C_6H_4)(C_6H_5)CNHC_6H_5$, phenyl lithium yields the normal product triphenylmethylaniline $(C_6H_5)_3C{\cdot}NHC_6H_5$.

PHYSICAL CHEMISTRY. By O. H. WANSBROUGH-JONES, Ph.D., M.A., Department of Colloid Science, Cambridge.

To describe the recent progress in the numerous photochemical studies that are now being pursued is a difficult problem for two reasons, firstly because the work while directed towards clearing up one point often actually reveals new difficulties, and secondly the number of phenomena to be described is so great that it is difficult to obtain a clear view of the whole field. None the less,

it is probably desirable to make an attempt to describe some parts of this very interesting work, even though progress is rather more steady than rapid.

It is well known that it is generally possible and desirable to divide up photochemical processes into two main divisions, the primary and secondary stages, the first stage concerning itself only with the direct interaction of the light quantum with the molecule, and the second dealing with the subsequent fate of the molecule so activated, or the atom or radicals into which it may have been dissociated, whereby the theoretical quantum efficiency of unity may be increased or decreased. There are means of distinguishing primary and secondary processes, but it should be appreciated that in certain circumstances, as for instance reaction in a condensed phase, such a sharp division is not possible.

Of the three possible types of absorption spectra in which excitation may lead to reaction, the least interesting is that of discrete structure, and the only new point of much interest in connection with this arises from the work of Crone and Norrish (*Nature*, **132**, 241, 1933) on the fluorescence of acetone. The vapour, excited by light between 3,400 Å.U. and 2,800 Å.U., fluoresces between the region 5,500 Å.U. to 3,300 Å.U. The discrete structure in the acetone absorption band necessary to account for this was duly observed, but more interesting was the peculiar character of the emitted fluorescent light which was found to consist of fine sharp lines of rotational fine structure in the ultra-violet region, merging in the visible region to a series of diffuse bands similar to those in the normal pre-dissociation region.[1] This appears to be the first case of such pre-dissociation in a fluorescence spectrum, which process would, according to Crone and Norrish, involve a new type of primary reaction, in which absorption and excitation to a high stable level is followed by fluorescence, as a result of which the molecule reverts to a lower unstable level and

[1] It is a common phenomenon in the study of absorption spectra for such bands to be observed. Regions showing discrete fine structure with well-marked rotational lines are often succeeded by discrete bands in which the rotational fine structure is lacking, or "smeared out," before they merge into the continuous region. Such discrete bands, showing no rotational fine structure, are known as pre-dissociation bands, and the excitation process involved may be considered to be an electron transition to the upper level reached in the region of fine structure; but which, by reason of the high vibrational energy, undergoes a spontaneous radiationless transition in less than the rotational period to an unstable excited state which at once dissociates. Thus absorption in the region of pre-dissociation will result in the dissociation of the molecule, an experimental observation which led to the theoretical description given above.

promptly dissociates. The experiment is an interesting one, which may lead to valuable results, and it is to be hoped that similar processes will be observed in other molecules. It may be added that the energy relationships are at least qualitatively in order. Fluorescence in acetone vapour had also been observed by Damon and Daniels (*J.A.C.S.*, **55**, 2363, 1933) who obtained results for the products of decomposition, and compared the efficiencies of the processes ; finding some 17 per cent. of the molecules broke down, 3 per cent. fluoresced, and the remainder lost their energy by collisions which did not lead to any reaction.

Fairly closely allied to fluorescence following absorption in a discrete region are the processes by which aldehydes and ketones decompose after illumination in their region of pre-dissociation. There are several experiments reported on this subject (Norrish, *Trans. Far. Soc.*, 1933 ; Leighton and Blacet, *J.A.C.S.*, **54**, 3165, 1932 ; Kirkbride and Norrish, *Trans. Far. Soc.*, **27**, 404, 1931 and *J.C.S.*, 1518, 1932). The original view that the aldehyde, for example, would break down in a single act ($RCHO \rightarrow RH + CO$) would seem to need modification to bring it into agreement with later work on the ketones, in which it is clear that free radicals are produced (Norrish and Miss Appleyard). Thus illumination of methyl ethyl ketone gives rise to fair quantities each of ethane, propane, and butane together with carbon monoxide ; clear indication that

$$\begin{matrix} R \\ R^1 \end{matrix}\!\!>\!CO \rightarrow \overset{|}{R} + R^1\overset{|}{C}O$$

must be regarded as the primary act. The absence of measurable quantities of diketones indicates that the radical containing the carbonyl group must be very unstable, and suggests then that for the aldehydes the subsequent spontaneous decomposition $H\overset{|}{C}O \rightarrow H + CO$ occurs so rapidly that the H atom and the R radical are never sufficiently separated to allow a reasonable chance of the $R + H \rightarrow RH$ reaction not taking place. This may be one of the fairly numerous cases in which the distinction between primary and secondary processes is rather fine. Leighton and Blacet (loc. cit.) state that in general the reaction of aldehyde molecules in light is to give hydrocarbon and carbon monoxide ($RH + CO$) to the extent of more than 80 per cent. and to give the alternative reaction ($RCHO \rightarrow \frac{1}{2} R_2 + \frac{1}{2} H_2 + CO$) to the extent of less than 20 per cent. The decomposition of diazomethane has been shown by Kirkbride and Norrish (loc. cit.) to have a primary stage $CH_2N_2 \rightarrow CH_2 + N_2$, while ketene (Norrish, Crone and

Saltmarsh) follows the analogous change $CH_2CO \rightarrow CH_2 + CO$, and in these cases the subsequent behaviour of the CH_2 radical has been fully observed; some points of more than usual significance are introduced when the energy relations are considered, and it seems that the CH_2 radical must be regarded more as a molecule of di-valent carbon than as a radical of tetra-valent carbon. There is no difficulty inherent in this conception (see Lennard-Jones, *Trans. Far. Soc.*, 1933), but it involves some variation in many of the accepted values for the heats of dissociation of the bonds linking atoms to carbon, since most of them had been calculated without making the correct allowance for this "energy of reorganisation," *i.e.* the thermochemical change in going from tetra- to di-valent carbon (cf. Faraday Society discussion, "Free Radicals," Oct. 1933). A decomposition of an organic vapour similar to that shown by the aldehydes may be found in that of acetic acid (Farkas and Wansbrough-Jones, *Z. Phys. Chem.*, B, **18**, 124). The reaction is more complicated since there are two species, the single and double molecules, of acetic acid present in the gas phase There is no evidence against the simple view that the single molecule decomposes in a single act to give $RH + CO_2$, though admittedly if a very unstable radical analogous to the $\mathrm{H\overset{|}{C}O}$ were produced which instantaneously underwent spontaneous dissociation a similar result might be given. The double molecules seem to undergo a more complicated decomposition to give

$$CO + CO_2 + C_2H_6 + H_2O.$$

It will be seen that the primary act cannot always be readily disentangled from the subsequent processes. There are, however, some reactions in which it is certain that the primary reaction can be isolated; and one of the more interesting of these is the reaction following irradiation of the halides of the alkali metals; and, of special technical importance, of silver. The work of Hilsch and Pohl (*Z Phys.*, **77**, 421, 1932; *Naturwiss*, **14**, 261, 1933; and many earlier papers) has established conclusively that the primary act is the simple transfer of an electron from the anion to the cation, leaving the atoms of alkali metal and chlorine in general in an excited state. The proof of this theory comes in part from the detailed examination of the absorption spectra of these substances, in particular in the identification of the maxima in their continuous spectra, and in part from their photochemical behaviour. The free atoms produced have naturally quite different absorption spectra from the original salts, and it is found that the crystals become coloured on prolonged illumination with short ultra-violet light.

Thus for example potassium bromide prepared in the dark shows no absorption between 2,100 Å.U. and the infra red; but after illumination with light of 2,030 Å.U. a new band appears at 6,300 Å.U. This can be removed by suitable means, meaning that the electrons which had been shifted from the anions to the cations fall back to their original position, and since they have an appreciable distance to travel, this process involves an appreciable electrical disturbance which may actually be observed with an electrometer. This electrical effect is, however, a secondary effect, and the primary one—the formation of the latent image—is the electron transfer. The effect in silver halides is exactly similar, and it has been possible to show, by measurements of the amount of colouring, that the quantum efficiency of this process lies very near to unity. An interesting additional case has been found in Lithium Hydride, in which the electron transferred from the lithium to form a hydrogen anion (cf. electrolysis experiments of Bardwell, *J A.C.S.*, **44**, 2499, 1922) returns to the lithium cation after illumination, freeing lithium and hydrogen (Bach and Bonhoeffer, *Naturwiss*, **13**, 940, 1932). The examination of the photochemical thresholds of these processes in the light of information available on the electron affinity of the anion (cf. Mayer and Helmholz, *Z. Phys.*, **75**, 1, 1932; Born and Mayer, **75**, 19, 1932), the ionisation potential of the cation, and the Coulomb portion of the crystal energy (cf. Born) which is now altered by substitution of atoms for ions in the lattice also give the position of the thresholds to be of the right order of magnitude; though Born has suggested that their exact position implies that this electron-transfer does not take place at all points in the crystal, but only at points where the crystal lattice is imperfect.

Directly analogous to these processes are the electron affinity spectra of ions (Franck and Scheibe, *Z. Phys. Chem.*, Haber Band, 22, 1928; Franck and Haber, *Ber. Berl. Akad.*, 250, 1931). Work on the spectra of aqueous solutions containing halide ions indicated that the absorption process involved the removal of an electron from the anion. Its subsequent fate could hardly be other than that expressed $Hl^-.H_2O + h\nu \rightarrow Hl + H + OH^-$;[1] and the photochemical threshold is in qualitative agreement with the thermochemical data available. Such electron affinity spectra appear to be quite general, but it does not follow that irradiation with the necessary light will cause a photochemical reaction to ensue for the back reaction may be very fast. In some cases, notably HI (Warburg and Rump, *Z. Phys.*, **47**, 305, 1928) a relatively high quantum output—reaching 2 in strong solution—is observed; in others, as

[1] Where Hl^- denotes a halide ion.

KCl (Butkow, *Z. Phys.*, **62**, 71, 1930), the back reaction is so fast that no free chlorine has been observed. The sulphite ion has been studied in some detail in view of the special interest attaching to the autoxidation of this material (Haber and Wansbrough-Jones, *Z. Phys. Chem.*, B, **18**, 103, 1932) and is found to decompose primarily according to the scheme.

$$SO_3^{=}.H_2O + h\nu \rightarrow SO_3^{-} + H + OH^{-}$$

and, in this case the quantum output is small (7 per cent. at pH 9·6), varying with the pH, and giving free hydrogen and sulphate ion as the main products. Suggested mechanisms for the secondary reaction are then the formation of undissociated HSO_3 and the back reaction $H + HSO_3 \rightarrow H^+ + HSO_3^-$ or the successful reaction $H + H_2O + HSO_3 \rightarrow H_2 + H_2SO_4$.

It may be significant that the quantum efficiency of such electron affinity processes is so often low; but the exact mechanism is not yet clear. Another case is that of the acetate ion (Farkas and Wansbrough-Jones, loc. cit., and Farkas, *Z. Phys. Chem.*, B, **23**, 89, 1933) which on illumination in neutral solution gives methane and CO_2; but in solutions of increasing alkalinity gives small amounts of hydrogen as well, though with a smaller gross quantum output. It may be mentioned that the decomposition of the organic acids in solution has also been studied by these authors and by Pierce and Morey (*J.A.C.S.*, **54**, 467, 1932). The process seems to be complex, for besides the elimination of carbon dioxide and the hydrocarbon in a manner analogous to the aldehydes and ketones there is another important reaction, the formation of the esters of formic acid. L. Farkas (loc. cit.) has made a more detailed study of the quantum efficiencies of the decomposition of these acids, and finds unity as a maximum with propionic acid, while acetic acid and succinic acid have respectively ·45 and ·40. These processes are probably worthy of further study, and in particular the influence of alkalinity and the addition of neutral salts to the organic acid ions.

It has been scarcely possible, in describing this work on solid and liquid phases, to distinguish between primary and secondary effects. With gases, however, it is generally easier. There are some classical photochemical gas reactions whose secondary mechanisms have lately received further study; and in some cases with most satisfactory results. The progress made in the studies on the hydrogen-chlorine reaction, the ammonia decomposition, and the photochemically sensitised formation of water will be briefly discussed.

The identification of the pre-dissociation absorption region of

ammonia between 2,200 Å.U. and 1,900 Å.U. and the immediate decomposition (*i.e.* in ca. 10^{-13} sec.) of the ammonia molecule on irradiation between these limits is well established, both by spectroscopical examination, and by the independence of the process on pressure and temperature. It is most likely that the primary process is $NH_3 \rightarrow NH_2 + H$, but the meaning of the quantum efficiency of 0·25 at room temperature and 0·50 at 500° C. is still obscure. Attempts to elucidate the mechanism have been several, and one of the most promising lines of attack is to measure directly the concentration of H atoms present during illumination of the gas. Geib and Harteck (*Z. Phys. Chem.*, Bodenstein Band, 861, 1931), and Harteck and L. Farkas (see Bonhoeffer and Harteck, *Gerundlagen der Photochemie*, 1933) have found that if this stationary concentration is measured by means of the now well-known para-ortho-hydrogen conversion (and expressed as the partial pressure of H atoms in millimetres of mercury) it is found to be very small (ca. 5×10^{-5} mm.). The rate at which H atoms are produced is clearly high (ca. 2×10^{-2} mm.) ; and thus the rate at which they are removed, whether by reaction or on the walls of the vessel, must also be high, too high in fact to be accounted for by a normal three-body collision. A curious experiment reported by Melville (*Trans. Far. Soc.*, **28**, 885, 1932) may be important in this connection ; it was found that when ammonia and mercury vapour were illuminated with the light from a zinc arc the rate of decomposition was greater than when in addition to the zinc arc of the same intensity a water-cooled mercury lamp was also used to irradiate the mixture. The hydrogen atoms formed by collisions of the second kind with excited mercury atoms diminish the total decomposition. This experiment suggests that increasing H atom concentration will result in a decreased decomposition of ammonia ; and the experiments with para-hydrogen indicated that something of this sort was the case. The exact mechanism is not clear, but it is clear that the rôle of the hydrogen atom is not a simple one. L. Farkas (loc. cit.) studied the decomposition of NH_3 in hexane solution. Here the pre-dissociation region has become merged in the continuous, but there is no reason to anticipate any different primary stage in the reaction ; the results show, however, that the ammonia acts only as a sensitiser for the decomposition of hexane, and can, itself be recovered unchanged, after such processes as

$$C_6H_{14} + NH_3 + h\nu \rightarrow C_6H_{13} + \tfrac{1}{2}H_2 + NH_3$$

and subsequent reaction of the radical. Thus there is some progress to report on this very important reaction.

The hydrogen chlorine reaction has received the study due to its position as the original photochemical reaction. It was surprising that its kinetics remained so obscure in view of the large amount of work that had been done on it, but the reasons for this are now fairly clear; firstly, differences in technique had played a part that had not been appreciated, and secondly its excessive speed had required the addition of amounts of inhibitor, notably oxygen, in order to make it more easily measurable, and this had naturally introduced further complications. There had been two main kinetic equations purporting to give the rate of reaction in mixtures containing oxygen, that of Chapman and Chapman (*J.C.S.*, **123**, 3002, 1923; 1802, 1928), and that of Bodenstein and his co-workers (cf. particularly Bodenstein, *Trans. Far. Soc.*, **27**, 413, 1931; Bodenstein and Unger, *Z. Phys. Chem.*, B, **11**, 253, 1931; Bodenstein and Schenck, *ibid*, B, **20**, 420, 1933) which seemed irreconcilable, though each was admittedly capable of explaining the experimental results of its respective author. The key to this problem has recently been given by Norrish and Ritchie (*Proc. Roy., Soc.*, A, **140**, 99, 1933; *ibid.*, pp. 112, 713) and lies in the hitherto unsuspected fact that HCl has a marked inhibiting effect on the rate of reaction. Chapman and his school had observed the course of the reaction by allowing it to take place in the presence of water, thus continuously removing the HCl; while Bodenstein's technique was to freeze out the chlorine and hydrogen chloride and measure the pressure of hydrogen at stated intervals. Their two methods are thus both open to objection, the first since no effect of HCl could be certainly detected, the second on the grounds that such a discontinuous process is rarely satisfactory. Norrish and Ritchie's method avoids both these troubles, continuous measurements being made of the chlorine concentration by measuring the light absorption in the reacting mixture with the aid of a thermopile. This technique works admirably, and with its aid these workers have definitely established the large inhibiting effect of hydrogen chlorine in mixtures of hydrogen and chlorine, with some oxygen. The effect is large, for example a certain mixture containing about 10 per cent of HCl had a quantum efficiency of about 150 (*i.e.* 150 molecules of HCl were produced by each light quantum absorbed); while when the percentage of HCl was raised to some 70 per cent., keeping the hydrogen and chlorine pressures constant (and in the presence of the same large amount of oxygen), it had fallen to about 20. With this established, Norrish and Ritchie returned to the apparently simple problem of mixtures containing no oxygen. Here again there had been a difference between the various schools

at work on the subject; Bodenstein's having found a rate proportional to the light intensity, Chapman's to its square root; and with certain other important differences respecting the inhibiting powers of the various gases in the mixture. There were then several questions to which definite answers could be given and the answers given by Norrish and Ritchie are in general agreement with the equation derived by Chapman. Naturally the main difference lies in the necessity for incorporating a term expressing the inhibiting power of HCl gas; this must presumably be due to a process $H + HCl \rightarrow H_2 + Cl$, though this point is as yet not completely settled; and it is worth noting that in 1926 Bonhoeffer and Boehm (*Zeit. Phys. Chem.*, **119**, 385, 1926) showed this to be a rapid reaction. It may be mentioned in passing that kinetic equations of the complexity necessary to account for all phases of this reaction necessarily contain a large number of constants, and are sometimes rightly suspected of thereby not proving that the mechanism by whose aid they are derived is necessarily the right one, and this criticism is indeed frequently valid. There is, however, always the possibility of finding the physical meaning of these constants and showing their numerical values to be reasonable. So far as practicable, Norrish and Ritchie have observed this precaution. Numerically their formula also gives a maximum quantum yield in good agreement with that obtained by other workers.

In a third paper, the effect of oxygen is discussed. Again there was disagreement, this time respecting the inhibiting effect of hydrogen; claimed by Chapman, denied by Bodenstein. It seems definitely established that the hydrogen has such an effect, and that the failure of Bodenstein to observe it was due to the presence of hydrogen chloride, the effect of which was unsuspected. A semi-empirical formula was derived which expresses satisfactorily all the facts over the whole range of concentration of the reacting gases.

Another effect in the hydrogen-chlorine reaction which had long been a puzzle seems also to have been cleared up. It had been claimed (cf. Cohen and Jung, *Ber.*, **56**, 1, 696, 1923) that completely dry hydrogen and chlorine would not combine when illuminated. This was naturally exceedingly difficult to explain, but the claim seems to have been disproved, and the effect observed is ascribed now to the accidental presence of small particles of gold chloride (cf. Bodenstein and Bernreuther, Rodebush, *J.A.C.S.*, 130, 1933; Rodebush and Klingelhoefer, *ibid.*, p. 860). Thus the chain reaction mechanism may remain unchanged.

The third important reaction that should be mentioned is the photo-sensitised formation of water, and in this case the situation

cannot be said to be clear. There have been many papers on this subject, and on the whole it seems clear now that the original mechanism of Haber and Bonhoeffer (*Zeit. Phys. Chem.*, A, **137**, 263, 1927)

$$HO_2 + H_2 \rightarrow HO_2 + OH\ ;\ OH + OH \rightarrow H_2O_2\ ;\ HO_2 + H_2O \rightarrow H_2O + OH$$

requires revision (cf. also Frankenburger and Klinkhardt, *Z. Phys. Chem.*, **15**, 421, 1932). Briefly, the yield of hydrogen peroxide in favourable circumstances in the production of water in the presence of HI, NH_3, or mercury vapour (Bates and Lavin, *J.A.C.S.*, **55**, 81, 1933; Taylor and Salley, *ibid.*, 96, 1933; Bates and Salley, *ibid.*, 110, 1933 respectively) is generally too high to be accounted for by this mechanism. It seems quite clear that the primary formation of hydrogen atoms is followed by their reaction with oxygen molecules to give an unstable HO_2 molecule; but the species of collision, three-body or fast or slow two-body, is not certain. The mechanism preferred by the American authors is

$$HO_2 + H_2 \rightarrow H_2O_2 + H\ ;\ HO_2 + HO_2 \rightarrow H_2O_2 + O_2.$$

The life time of the HO_2 molecule is most uncertain, but it may be as much as 10^{-8} to 10^{-9} sec. even if it has undergone no stabilising three-body collision. The relationship of these processes with the chain mechanism in chlorine, hydrogen, oxygen mixtures is also most important, but the writer feels that at the moment too much uncertainty exists for it to be valuable to do more than mention the fact that much valuable and interesting work is being actively pursued on these subjects.

In a report of this length it is quite impossible even to mention all important photo-chemical papers. There are several other branches of the subject which certainly deserve mention, as for example Rabinovitsch's work on reaction in solution (*e.g.* on photo bromination of Benzene, *Z. Phys. Chem.*, B, **19**, 190, 1932; and a general paper at the Faraday Society Discussion on Free Radicals, 1933); several specific decompositions such as Cl_2O (Schumacher and Townsend, *Z. Phys. Chem.*, B., **20**, 375, 1933), phosgene (Almasy and Wagner-Jauregg, *ibid.*, B, **19**, 405, 1932) NCl_3 (Norrish and Griffiths, *Proc. Roy. Soc.*, **135**, 69, 1932) and the like. Polymerisation by light has also received attention (cf. Lind and Livingstone on acetylene, methyl-acetylene, and allene, *J.A.C.S.*, **54**, 94, 1932; *ibid.*, 1036, 1933) and the study of inhibitory powers for such reactions, in which this power for some sixteen different substances is nearly identical either for the autoxidation of sodium sulphite or for the photo polymerisation of vinyl acetate (Kia-

Khwe Jeu and Alyea, *J.A.C.S.*, **55**, 575, 1933). If one single point emerges more clearly than any other from this general survey, it is that the closest co-operation between the mathematician, the band spectroscopist, and the photochemist is the first necessity. It is perhaps also worth recording the publication of an excellent discussion of Photochemical Reactions by Bonhoeffer and Harteck in their book *Grundlagen der Photochemie*, Theodor Steinkopff, Leipzig, 1933.

GEOLOGY. By G. W. Tyrrell, A.R.C.Sc., D.Sc., The University, Glasgow.

Stratigraphy and Regional Geology: Europe.—Of extraordinary interest and revolutionary significance is O. Holtedahl's discovery of plants of Lower Permian age in sediments which underlie the "essexite lavas" of the Oslo region in the Baerum district ("Jungpaläozoische Fossilien im Oslogebiete," *Norsk Geol. Tidsskr.*, XII, 1932, 323–39). The lavas and intrusions of the classic Oslo (Kristiania) petrographic province are thus determined as of Permian age instead of Devonian as formerly, and are completely removed from the sphere of influence of the Caledonian folding. This discovery also brings the Oslo petrographic province into line with the Scottish Carboniferous-Permian igneous field, and thus resolves a perplexing petrological problem.

Professor Holtedahl has also brought his work on the geology of Northern Norway up to date by the publication of "Additional Observations on the Rock Formations of Finmarken, Northern Norway," (*Norsk Geol. Tidsskr.*, XI, 1931, 241–79).

Dr. N. H. Kolderup explains the succession and structure of a region about the Hardanger Fjord with the aid of an instructive block diagram ("Kyst- og Höifjell-stil i Foldningsgröften i Vest-Norge," *Geol. För. Förh. Stockholm*, **54**, 1932, 269–78). The sequence in this trough structure is: basal mica-schists (Ordovician), quartzite ("Granulite"), green schists and trap, and upper mica-schists. Overthrust masses of Pre-Cambrian granite, basal mica-schists, and quartzite, are found superposed on the normal sequence.

Dr. J. J. Sederholm's memoir "On the Geology of Fennoscandia, with Special Reference to the Pre-Cambrian" (*Fennia*, **55**, No. 2, 1932, 30 pp.) represents explanatory notes to accompany a new general geological map of Fennoscandia. In it he now recognises four cycles of Pre-Cambrian supracrustal and igneous rocks.

The "Compte Rendu de la Réunion internationale pour l'étude du Pré-Cambrien et des vieilles chaines de Montagnes en Finlande 1931" (Helsingfors: Government Press, 1933, 46 pp.) has now been

published. It contains a record of much valuable work carried on during a pleasant conference and an interesting series of excursions by a party of geologists belonging to nineteen nationalities. A useful summary of the excursions is given by Dr. E. H. Kranck; and papers on "Greenstones and Greywackes" by G. W. Tyrrell, and on "Les traits caractéristiques des terrains précambriens de la Péninsule Ibérique," by M. Faura y Sans, are published. Dr. F. von Wolff has published an extremely useful discussion and summary of the Pre-Cambrian of Finland (*Geol. Rundsch.*, XXIII, 1932, 89–121) based on the recent work of Sederholm, Eskola, Wahl, Wegmann, Kranck, and Mikkola. This memoir represents the fruits of Professor Wolff's visit to Finland in connection with the above-mentioned conference He discusses the subdivision, tectonics, and metamorphism of the Finnish Pre-Cambrian, the origin of orbicular granite, and the differentiation of Rapakiwi granite and Högland porphyry (see SCIENCE PROGRESS, Jan. 1933, p. 434).

From the evidence of current bedding Dr. W. J. McCallien, another member of the above conference, thinks that the contact section between diorite breccia and sedimentary schist at Jaakkola (Finland) described by Sederholm and interpreted by him as indicating normal subaerial weathering of an older diorite (see SCIENCE PROGRESS, April 1932, p. 582), really shows an intrusive junction of diorite against schist (*Geol. Mag*, LXIX, 1932, 268–73).

In a critical reply to Dr. McCallien's contentions Dr. Sederholm asserts the insufficiency of the criterion of current bedding to settle the question of the nature of the igneous-sedimentary rock contacts exposed in the Suodenniemi region (*Geol. Mag.*, LXX, 1933, 232-6). He reaffirms his conclusions as to the origin of the schists and breccias from older diorites by subaerial weathering.

An important memoir (in Russian) on the geological history of the Black Sea, by A. D. Archanguelsky and N. M. Strahov (*Bull. Soc. Nat. Moscou, sect. gèol.*, **10**, Pt. 1, 1932, 3–104) has been summarized in *Nature*, July 1, 1933, page 32.

THE BRITISH ISLANDS.—The Dalradian succession in Islay and Jura has been worked out by A. Allison (*Quart. Journ. Geol. Soc.*, LXXXIX, 1933, 125–44) by the study of small-scale and large-scale current bedding, graded bedding, and the relationships of conglomerates. The results of this close and fruitful investigation corroborate in large measure the stratigraphical succession and structure of this region put forward by Professor E. B. Bailey in 1917, and appear to refute the views of Mr. J. F. N. Green and the late Professor J. W. Gregory.

In his paper on "The Green Beds of South Knapdale," Dr.

W. J. McCallien (*Geol. Mag.*, LXX, 1933, 156–67) shows that typical "green beds," whilst occurring mainly on one definite horizon, are to be found as intercalations over a much wider stratigraphical range. Their distribution could be explained if deposition of the basic material of which the green beds are composed began abruptly and profusely at the end of Bheinn Bheula times, and continued in decreasing amount till towards the end of Ben Lui times.

The remote Hebridean islets of Sula Sgeir and the Flannans, respectively north and west of Lewis, have been visited by M. Stewart (*Geol. Mag.*, LXX, 1933, 110–16). Both islands consist of hornblende-gneisses with veins of pegmatite, which are probably of Lewisian age.

L. R. Wager describes the geology of the Roundstone District of Co. Galway (*Proc. Roy. Irish Acad*, XLI, Sect. B., No. 5, 1932, 46–72). The district consists of metamorphic sediments and injection-gneisses, epidiorites, hornblende-schists, two series of basic and ultrabasic plutonic igneous rocks, followed by invasion of quartz-diorite magma in gneissic form. The final episode was the injection of three distinct transgressive masses of granite. The whole series of igneous events is tentatively relegated to the Pre-Cambrian.

Welsh and English Border stratigraphy is represented by the following papers: K. A Davies, "The Geology of the Country between Abergwesyn (Breconshire) and Pumpsaint (Carmarthenshire)" (*Quart. Journ. Geol Soc.*, LXXXIX, 1933, 172–201); K. A. Davies and J. I. Platt, "The Conglomerates and Grits of the Bala and Valentian Rocks of the District between Rhayader (Radnorshire) and Llansawel (Carmarthenshire)" (*ibid.*, 202–20); B. Jones, "The Geology of the Fairbourne-Llwyngwril District, Merioneth" (*ibid.*, 145–71); W. F. Whittard, "The Stratigraphy of the Valentian Rocks of Shropshire. The Longmynd-Shelve and Breidden Outcrops" (*ibid.*, LXXXVIII, 1932, 859–902); P. G. H. Boswell, "On the Occurrence and Significance of an Area of Imbrication in the Ludlow Rocks of the Denbighshire Moors" (*Proc. Liverpool Geol. Soc.*, XVI, 1932, 18–32). In this paper Professor Boswell suggests that the imbrication, like the tear-faulting, is due to spiral movements acting in a clockwise direction. These movements spent themselves on the Silurian rocks of the western Denbighshire Moors, thrusting them northwards and westwards, while the Ordovician floor remained stable. Professor Boswell thinks that spiral movements of the type here described will be found to be more widespread than hitherto thought.

The following are notable recent papers on the structure and stratigraphy of Carboniferous rocks within the south-western region

of Great Britain: F. B. A. Welch, "The Geological Structure of the Eastern Mendips" (*Quart. Journ. Geol. Soc.*, LXXXIX, 1933, 14–52); T. N. George, "The Carboniferous Limestone Series in the West of the Vale of Glamorgan" (*ibid.*, 221–72).

Professor W. S. Boulton has written a paper on "The Rocks between the Carboniferous and Trias in the Birmingham District" (*Quart. Journ. Geol. Soc.*, LXXXIX, 1933, 53–86) in which he shows that some of the rocks formerly classed as Hopwas Beds must now be grouped definitely with the Trias. He suggests the term "Clent Beds" as a group-name for the various pre-Triassic breccias which postdate the Calcareous Conglomerate group.

In connection with the above F. W. Shotton's recent paper on "New Evidence on the Origin of Breccias and Conglomerates in the Warwickshire Coalfield. The Mount Nod Boreholes, Coventry" (*Geol. Mag.*, LXX, 1933, 466–76) must be mentioned. Mr. Shotton, on the basis of evidence therein assembled, would still classify the Kenilworth-Clent breccias as Carboniferous, although he doubts whether the words "Carboniferous" or "Permian" have any real meaning in the Midlands.

The late Dr. G. W Lee left an unfinished draft account of the Jurassic and Cretaceous rocks of Scotland which was apparently written about 1915. Dr. J. Pringle has brought this work up to date by incorporating later information (*Trans. Geol. Soc. Glasgow*, XIX, Pt. I, 1932, 158–224). He has thus produced a highly interesting and valuable summary of these Mesozoic rocks which owe their preservation to burial beneath Tertiary lava floods in the west, and in the east to powerful faults.

Recent Geological Survey memoirs include the following: W. Lloyd, "The Geology of the Country around Torquay" (*Expl. of Sh. 350*, 1933, 169 pp.) (Devonian); R. G. Carruthers, G. A. Burnett, and W. Anderson, "The Geology of the Cheviot Hills" (*Expl. of Shs. 3 and 5*, 1932, 174 pp.) (Old Red Sandstone and Carboniferous); F. M. Trotter and S. E. Hollingworth, "The Geology of the Brampton District" (*Expl. of Sh. 18*, 1932, 223 pp.) (Carboniferous and New Red Sandstone); T. Robertson, "The Geology of the South Wales Coalfield; Part V, The Country around Merthyr Tydfil, 2nd Ed. (*Expl. of Sh. 231*, 1932, 283 pp.) (Carboniferous); C. E. N. Bromehead, W. Edwards, D. A. Wray and J. V. Stephens, "The Geology of the Country around Holmfirth and Glossop" (*Expl. of Sh. 86*, 1933, 209 pp. (Millstone Grit and Coal Measures); H. J. Osborne White, "The Geology of the Country near Saffron Walden" *Expl. of Sh. 205*, 1932, 125 pp.) (Cretaceous and Pleistocene).

Professor P. G. H. Boswell's Presidential Address to Sect. C

(Geology) of the British Association at York 1932 ("The Contacts of Geology: The Ice Age and Early Man in Britain," *Rept. Brit. Assoc., York,* 1932, pp. 57–88) was, in the main, a detailed study of the succession of events in Great Britain during the Pleistocene and their relation to Early Man. This most valuable summary, which is accompanied by a detailed table of correlation, will be of the greatest use to workers in Pleistocene geology, and will prove a starting-point for renewed investigations into this fascinating but difficult subject.

J. D. Solomon's work on "The Glacial Succession on the North Norfolk Coast" (*Proc. Geol Assoc.,* XLIII, 1932, 241–71) has been carried out mainly by field observation aided by heavy mineral analyses. He has been enabled to recognise twelve divisions in the succession of Quaternary deposits in the Cromer area, which are referable to four distinct periods of ice-advance to which the names North Sea, Great Eastern, Little Eastern, and Hessle have been given.

A paper by J. B. Simpson on "The Late-Glacial Readvance Moraines of the Highland Border West of the River Tay" (*Trans. Roy. Soc. Edin.,* LVII, Pt. III, 1933, 633–46) describes and discusses the significance of the extensive morainic deposits and associated glacial phenomena of the region immediately west of the Ochil Hills (Perth Region), as well as the well-marked later glaciation of Loch Lomond and the Upper Forth. The Perth readvance was nurtured entirely from the Grampians and received no increment from the Ochil Hills. The Loch Lomond readvance came somewhat later in time than the Perth. Loch Lomond at this time was an arm of the sea as is proved by the presence of marine fossils in both boulder-clay and surface moraines.

North America.—Attention is drawn by C. Tolman to a thick series of altered sediments which are conformably intercalated with the Keewatin volcanic series in Northern Quebec (*Journ. Geol.,* XL, 1932, 353–73). These sediments are of highly feldspathic composition, arkose, grit, and conglomerate being the most common rock types. They are believed to have originated from the weathering of a syenite complex under arid conditions.

Professor C. Schuchert has summarised much recent work on the famous Taconic region of New England by himself, his colleagues, and other workers in his paper entitled "Cambrian and Ordovician Stratigraphy of Northwestern Vermont" (*Amer. Journ. Sci.,* XXV, 1933, 353–81).

Another classical region of New England geology—the Boston area of Massachusetts—has been fully described by L. LaForge (*U.S. Geol. Surv., Bull. 839,* 1932, 105 pp.). Some notable departures

from the traditional view of the succession and structure of this area have been made on the basis of recent investigation.

Two papers which deal with structural rather than stratigraphical problems, but which cover American formations, are the following: P. H. Price, "The Appalachian Structural Front" (*Journ. Geol.*, XXXIX, 1931, 24–44); S. K. Clark, "The Mechanics of the Plains-Type Folds of the Mid-Continent Area" (*Journ. Geol.*, XL, 1932, 46–61).

The "crystallines" of Alabama, of which the general geology is described by G. I. Adams (*Journ Geol*, XLI, 1933, 159–73), represent the extreme south-western portion of the Archæan element in the Appalachian mountain system. Several schistose formations of sedimentary origin, with one granite and an altered basic sill now chlorite-schist, have been discriminated and mapped. Mr. Adams has also noted a diabase dike which probably belongs to the Newark igneous episode of the Triassic.

An exhaustive study of the stratigraphy and palæontology of the Ordovician, Silurian, and Carboniferous systems building the central basin of Tennessee has been made by Dr. R. S. Bassler (*Tennessee: Dept. of Education, Division of Geology, Bull. 38*, 1932, 268 pp.).

An area of Middle Ordovician strata covering about half a square mile in north-west Indiana has been uplifted 1,500 feet and intensely disturbed by fracturing and faulting. This occurrence is described by R. R. Schrock and C. A. Malott (*Journ. Geol.*, XLI, 1933, 337–70), who ascribe the phenomena to "cryptovolcanic activity," *i.e.*, the intrusion of a deeply-buried plug of igneous rock under a comparatively light load.

The boulder-beds of the Carboniferous Caney Shale in the Ouachita Mountains of south-east Oklahoma contain material of exotic provenance. According to W. B. Kramer (*Journ. Geol.*, XLI, 1933, 590–621) these boulders are derived from "Bengalia," a land which existed along the northern side of the Ouachita trough throughout most of Palæozoic time. Earthquakes accompanying downwarping of the trough are believed to have caused submarine landslips of boulders from Bengalia into Carboniferous shales which were forming on the north-western side of the depression. This author appears to have overlooked E. E. L. Dixon's paper on "The Ouachita Basin of Oklahoma *vis-a-vis* the Craven Lowlands of Yorkshire" (*Geol. Mag.*, LXVIII, 1931, 337–44) in which a similar theory of origin is suggested.

The "Geology of the Arkansas Palæozoic Area" has been described by C. Croneis in a massive memoir (*Ark. Geol. Surv. Bull. 3*, 1930, 457 pp) which is reviewed in *Geol. Mag.*, LXVIII, 1931, 432.

A formation comprising a tillite over 300 feet thick, with fluvial conglomerate, varved slate, and greywacke, occurs in the Wasatch Mountains and on islands in the Great Salt Lake of Utah, and has been described by E. Blackwelder (*Journ. Geol.*, XL, 1932, 289–304). It underlies Cambrian terranes with mainly disconformable relations.

The Stockton and Fairfield Quadrangles, Utah, the geology and ore-deposits of which have been described by J. Gilluly (*U S. Geol. Surv.*, *Prof. Paper 173*, 1932, 171 pp.) cover the southern part of the Oqirrh Range, which consists of Cambrian quartzite, shale, and limestone, unconformably overlain by Devonian dolomites, which are in turn unconformably covered by rocks of Mississippian and Pennsylvanian ages. Folding took place between the Cretaceous and Tertiary followed by great volcanic activity and subjacent injection.

Other United States Geological Survey memoirs on western mining regions on the same lines as the above are the following: W. S. Burbank, " Geology and Ore-Deposits of the Bonanza Mining District, Colorado " (*U.S. Geol. Surv.*, *Prof. Paper 169*, 1932, 166 pp.); L. G. Westgate and A. Knopf, " Geology and Ore Deposits of the Pioche District, Nevada " (*U.S. Geol Surv*, *Prof. Paper 171*, 1932, 79 pp.). The U.S. Geological Survey has also published several valuable memoirs dealing with the physiographical and glacial history of various western regions The following list gives the most important of these: F. E. Matthes, " Geologic History of the Yosemite Valley " (*Prof. Paper 160*, 1930, 137 pp.); W. C. Alden, " Physiography and Glacial Geology of Eastern Montana and Adjacent Areas " (*Prof. Paper 174*, 1932, 133 pp); W. W. Atwood and K. F. Mather, " Physiography and Quaternary Geology of the San Juan Mountains, Colorado " (*Prof. Paper 166*, 1932, 176 pp.).

BOTANY. By Professor E. J. Salisbury, D.Sc., F.R.S., University College, London.

Ecology.—An account by T. W. Bocher of the Flora of Greenland between Scorsby Sound and Angmagssalik (*Phytogeographical Studies of the Greenland Flora*, Copenhagen, 1933) has just appeared in which thirty-five species are added to the 115 already known from this region. An account of their distribution shows that the southern species extend farthest north inland, which is attributed to warmer conditions away from the coast. Similarly many of the northern types have their southern limits also inland, a fact attributed to intolerance of the oceanic conditions of the coastal zone. A floristic and ecological boundary is recognised as occurring between 68° N.

and 69° N. and indeed some fifty-two species, or about one-fifth of the phanerogamic flora of East Greenland have their northern or southern limits between 68° 30′ and 69° 30′. High meadow with tall herbs is a vegetation type which dies out north of this zone, whilst the southern limit of Cassiope Heath occurs here also. This boundary also marks a zone of abrupt increase northwards of chamaephytic species. The author, from an examination of published accounts, suggests that the corresponding limit on the west coast is probably about 71° N.

O. Hargem (*Kalkvirking paa Kulturbeite*, Bergen, 1933) reports interesting results of experiments, in which calcium was added to the surface of acid soils, showing that the ameliorating effect on the reaction is very superficial. Even with 450 kg. of lime per dekar, which changed the surface reaction from *p*H. 5·5 to over *p*H. 7, the reaction at a depth of 9 cm. had only changed after two or three years from *p*H. 4·8 to *p*H. 5 This meagre influence on the underlying horizons appears to be characteristic of heath and moorland soils rich in unsaturated humus compounds which adsorb the calcium ions. This too may account for the marked stratification of woodland soils with respect to Hydrogen-ion concentration noted by Salisbury (*Jour. Ecol.*, IX, pp. 220–40, 1922).

High values for *Tilia* pollen are recorded by H. and M. E. Godwin from early Bronze Age horizons in the peat near Ely. The peat of the Fens would appear to have begun to form during late Boreal times (*Antiquaries Journal*, p. 281, 1933). Similar high values for *Tilia* pollen have been obtained by the same investigators at St. Germans near Kings Lynn (*Geol. Mag.*, p. 168, 1933). The Mat types of vegetation of West Greenland are described by C. G. Trapnell (*Jour. Ecol.*, XXI, 294–334), the distribution of which would appear to depend mainly on the depth and duration of the snow covering and the degree of insolation. The microrelief thus plays an important rôle and the various combinations of microclimatic and geomorphic factors result in a great diversity of climax communities.

The little-known Venezuelan llanos are described by J. G. Myers (*ibid.*, pp. 335–49). Bunch grass savannah is the most frequent type, with *Cymbopogon rufus* as the chief dominant and, over smaller areas, *Andropogon condensata* and *Sporobolus indicus*. The riverine tracts subject to heavy inundation are however occupied by high grass savannah with *Paspalum fasciculatum* as the dominant. All these are subject to annual fires caused either by man or by lightning, but the author expresses the view that there is no evidence that the llanos are encroaching on the forest from this cause. Selective grazing has, however, apparently brought about local dominance

of the labiate *Hyptis suaveolens* in the drier heavily grazed areas and of *Ipomœa crassicaulis* in the wetter.

An intensive study of Guiana Rain-Forest is furnished by T. A. Davis and P. W. Richards (*ibid.*, pp. 350–84) from which it appears that the physiognomy is comparatively simple. Only two distinct tree-layers are recognisable, at about 14 m. and 24 m. respectively, though isolated trees of greater height occur. The vertical distribution of epiphytes is shown to be mainly dependent upon light intensity though humidity and bark surface are subsidiary influences. Three strata of climbers are present, and there is an herbaceous stratum of scattered patches of saprophytes in the shadier areas and of green-leaved social species (*e.g. Leandra divaricata*) where the light penetrates more readily. Measurements of the humidity, saturation deficit, and temperature emphasise the extremely uniform conditions in the lower part of the forest.

A paper in the same journal by A. S. Watt and G. K. Fraser (pp. 404–14) draws attention to the competitive influences of the root systems of the tree and herbaceous strata of the forest, despite the complementary character of their spatial distribution.

A paper by P. S. Gupta (*ibid.*, pp. 452–74) deals with the much-neglected subject of the effects of soil texture on plant growth. The author shows that, in a soil of uniform composition, differences in the degree of packing of the soil particles greatly affect its water-retaining and particularly its water-supplying power. It is also shown that the penetrability varies directly with the water content and in natural soils usually diminishes with increasing depth.

Rubus cissioides occurs in New Zealand in two markedly different forms. The one is a liane of the forests bearing leaves with relatively short petioles and well-developed laminæ. The other grows in exposed sunny situations and assumes a bolster-like habit. The leaves of the latter have very well developed petioles and leaflet-stalks, but the laminæ are almost, or completely, undeveloped. Cockayne reports that the seedlings show the type of foliage characteristic of the bolster-form. Since the bolster-form does not flower and bears the seedling form of leaf it would appear to be a persistent juvenile type (*Amer. Jour. Bot.*, XX, 545, 1933).

Skutch, in the last-named journal (p. 535) records a remarkable example of the retention of aquatic conditions by the Central American *Heliconia bihar*. The erect inflorescence consists of groups of flowers in the axils of bracts so constituted that water is retained around the flowers. Both flower buds and developing fruits are completely submerged in the reservoirs thus formed, and it is only at anthesis that the water-tight perianth emerges above the water

surface. Though nectar is secreted and the flowers are visited by humming birds, self-fertilisation occurs freely and is perhaps normal.

The intermittent germination of *Helianthemum guttatum* has been investigated by D. V. Juby and J. H. Pheasant (*Jour. Ecol.*, XXI, 442), who find that this intermittence is a constant feature which however disappears when the testas are removed. The phenomenon is probably of considerable biological importance and appears to depend on physiological dimorphism in the seeds. Some of these have relatively impermeable testas and others are easily permeable. The hard seeds show a wide range of variability in respect to their permeability. Germination extends over a period of from 200 to 300 days with an optimum of germination about 10 days after sowing. From then onwards the germination proceeds at intervals as a result of which disasters which may overtake some of the seedlings are unlikely to destroy the entire progeny. The seeds of *Plantago coronopus* have been found by R. Dowling to be morphologically dimorphic. The two types of seeds occur in the same capsule and differ, in size and in the degree of development of mucilage by the seed coat when wetted, and also in their mode of dispersal. The larger seeds which have copious mucilage germinate soon after being shed. The small seeds which have little mucilage are shed enclosed in the capsule lid and this enclosure causes delayed germination. The species, often stated to be annual, is shown to persist for several years and to exhibit vegetative propagation (*Ann. Bot.*, XLVII, 861–72). In the same journal (pp. 873–81) A. W. Hill describes the mode of germination of some seeds with stony endocarps in which liberation of the embryo is brought about by detachment of a predetermined area of the sclerotic covering. The number of these valves, one in *Nyssa*, two in *Cornus*, or several, corresponds to the number of seeds contained in the fruit.

Cryptogamic.—An excellently illustrated account of the genus Volvox in Africa is given by F. Rich and M. A. Pocock in *Ann. S. A. Museum*, XVI, Pt. 3, which appreciably extends our knowledge of the distribution of these algæ. Two new species are described of which one, *V. capensis*, is intermediate between *V. globator* and *V. Rousseletii*, and the other, *V. ambœnsis*, is of large size, up to 1,300μ, and produces very numerous oospores. Both species are probably monoecious, thus differing from the dioecious, *V. Rousseletii*, which they otherwise somewhat resemble.

S. L. Ghose and M. S. Rahdhawa describe aplanospore formation in *Vaucheria uncinata*. Under drought conditions extensive septum formation occurs, and in the coenocytes so delimited, which vary

from 90 to 200 μ in length, the contents form from eight to numerous aplanospores (*Current Science*, p. 15, 1933).

An interesting *Protosiphon*, described as *V. deserti* of *P. botryoides*, is described by A. A. Nayal from the Egyptian desert (*Ann. Bot.*, XLVII, 758–98). The normal range of temperature in the desert is from a few degrees below zero to 70° C. and the soil may attain a solidity of 0·2 per cent. The protosiphon cysts are found to endure temperatures from 0° C. to 78° C. or even 91° C. if the rise in temperature be gradual. The young plants will grow in a salt concentration of 1 per cent. The cysts are red in colour and on germinating produce biciliated swarmers, which either grow directly into a new plant or fuse in pairs to form thick-walled stellate zygospores

The occurrence of latent infection of grasses by *Epichlœ typhina*, which may persist for several years without showing external evidence of the presence of the parasite, is recorded by K. Sampson (*Trans. Br. Mycol. Soc.*, XVIII, 30). The fungal hyphæ extend to all parts of the plant and viable seeds may contain hyphæ between and in the pericarp and endosperm and even in the embryo itself.

The capacity of mosses of dry habitats to conduct water externally has been investigated by E. J. Bowen (*Ann. Bot.*, XLVII, pp. 890–912) From this it appears that, except on mosses with a highly specialised conducting tract, such as *minium*, the external conduction is much more important than the internal.

Anatomy.—From a study of callus formation in *Hibiscus* and *Hevea*, A. Sharples and H. Gunnery (*Ann. Bot.*, XLVII, 825–38) conclude that the callus originates mainly in the parenchyma rays and that there is no indication of participation by the cambium until the callus cushion is laid down.

ENTOMOLOGY.

By H. F. Barnes, M.A., Ph.D., Rothamsted Experimental Station, Harpenden.

General Entomology.—C. T. Brues (*Amer. Nat.*, **67**, 1933, 385–406) has studied progressive change, since the early tertiary period, in the insect population of forests. His method has been to compare insects found in amber, which is fossilised resin, with insects which he has caught, on tangle-foot paper, in situations having the ecological conditions known to have existed in the amber forests. Several changes have been traced and the general conclusion reached is that many abundant groups of insects have passed their prime. One particular result of this study is, as the author

remarks, that Diptera show an enormous increase in abundance of individuals in spite of their great abundance already in the amber fauna. He goes on to state that we must look forward to them as representing the type that is well on its way to dominate in the insect world.

There is a lengthy and rather involved paper entitled "The Balance of Animal Populations," by A. J. Nicholson (*Jl. Animal Ecology*, **2**, 1933, 132–78). It is impossible to summarise this, but it may be remarked in passing that the main theme is competition always tends to cause animals to reach and maintain their steady densities. In a second contribution by H. F. Barnes towards a knowledge of fluctuations in insect populations (*loc. cit.*, **2**, 1933, 98–108), it is shown that reversal in the relative times of emergence of host and parasites may account for sudden changes in the degree of parasitism and subsequently changes in the extent of damage suffered by a crop. There is also some information concerning the variation from year to year in extent of damage by the sawfly, *Hoplocampa flava* L., in a paper on its biology by F. R. Petherbridge, I. Thomas and G. L. Hey (*Ann. Appl. Biol.*, **20**, 1933, 429–38). The influence of civilisation on the insect fauna of North America has been the subject of a symposium before the Entomological Society of America (*Ann. Ent. Soc. Amer.*, **26**, 1933, 497–528). S. A. Graham discussed the insect fauna of forests; P. W. Claassen that in regions of industrial activity; R. C. Smith that in cultivated areas; and H. S. Smith dealt with purposeful introductions.

While biological control of insects by insects has lost something of its first flavour, the control of weeds by insects is more fresh. H. W. Simmonds (*Bull. Ent. Res.*, **24**, 1933, 345–8) describes how the weed *Clidemia hirta* in Fiji has been controlled successfully by the introduction of *Liothrips urichi*: a thrips which does not directly kill the plant, but inhibits its growth, so that it is no longer able to compete with the surrounding vegetation.

H. Eltringham's presidential address to the Royal Entomological Society of London (*Proc. Ent. Roy. Soc. London*, **7**, 1933, 120–36) consisted of a very readable account of the senses of insects.

D. R. Mehta (*Q.J.M.S.*, **76**, 1933, 35–61) has investigated the development of the male genitalia and the efferent genital ducts in certain Lepidoptera. In a similar field of research Margot E. Metcalfe has followed up her work on the structure and development of the reproductive system in Coleoptera and *Philænus spumarius* by a paper (*loc. cit.*, pp. 89–105) on the female genital system in *Dasyneura leguminicola* (Diptera, Cecidomyidæ).

Madeleine von Dehn (*Zeits. Zellf. Mikros. Anat.*, **19**, 1933,

79–105) has dealt with the formation of the peritrophic membrane in insects.

J. H. Gerould (*Biol. Bull.*, **64**, 1933, 424–31) has described periodic or intermittent heart-beat reversal in representatives of the Diptera, Coleoptera, Lepidoptera and Hymenoptera. A compilation, with short summaries, has been made by C. A. Thomas (*Ent. News*, **44**, 1933, 91–6) of the references to phenomena in which imaginal organs occur in larvæ.

From time to time there have been reported instances in which parasitism has accelerated the development of insects. G. C. Varley and C. G. Butler (*Parasitology*, **25**, 1933, 263–8), after investigating two additional examples, have reviewed such cases and discussed them in the light of Raubaud's study of the diapause. He found that the diapause could be broken by certain types of shock such as singeing, pricking, centrifuging and sudden changes in temperature. Varley and Butler have come to the conclusion that the acceleration of development by parasitism in the case of certain flies is merely a special and natural case of this phenomenon.

Further results of the study of hardy fruit flower pollination by insects by G. F. Wilson are given in a recent paper (*Jl. R.H.S.*, **58**, 1933, 125–38). It deals with the insects together with notes on their habits when visiting the flowers and includes a complete list of insect species concerned at Wisley, 1920–30. C. P. Clausen (*U.S. Dept. Agric.*, *Circ. 266*, 1933, 35 pp.) has recorded approximately 200 species of insects which attack citrus in tropical Asia. Details are given as to their relative importance.

A noteworthy activity amongst amateur entomologists in recent years, is the establishment of the Insect Immigration Committee of the South Eastern Union of Scientific Societies and its scheme for collecting all records relating to insect migration into the British Isles. T. Dannreuther, the energetic honorary secretary, has enlisted the help of observers in numerous light vessels and lighthouses as well as that of many inland observers. C. B. Williams, the writer of a book and papers on insect migration, is responsible for co-ordinating the results. Particulars of this scheme may be found in *Bull. 62* (1933, 12 pp.) of the South-Eastern Union of Scientific Societies which contains the Secretary's report and an account by C. B. Williams of the results obtained in 1931–32, as well as lists of recorders, societies co-operating and the magazines publishing migration notes. Examples of such records may be found in the *Entomologist* (**66**, 1933, 186–90, 209–12 and 230–6). Further collected records relating to insect migration (*Trans. Roy. Ent. Soc. London*, **81**, 1933, 103–15) have been compiled by C. B.

Williams. This is the third of the series of such collected records that have been published, the previous ones having appeared in 1928 and 1930.

The development of technique is always interesting, and a paper by C. B. Bridges and H. H. Darby (*Amer. Nat.*, **67**, 1933, 437–72) describes, firstly, improvements in *Drosophila* culture methods and the rôle of yeast and, secondly, discusses the results obtained when using various cornmeal-molasses-agar media. They also suggest various possibilities in the further development of such media. O. A. Hills (*Jl. Econ Ent.*, **26**, 1933, 906–10) has described a new type of sampler for determining insect populations on plants. It consists essentially of a cage which can be placed suddenly over a plant, and from which the insects can be removed by suction. A suction pipette and a portable electric vacuum cleaner for this purpose are also described. A method for obtaining samples of the population of *Collembola* in pastures has been described by J. Davidson and D. C. Swan (*Bull Ent. Res.*, **24**, 1933, 351–2). There is also a description of a simple method of collecting thrips and other insects from blossoms by J. W. Evans (*loc. cit.*, pp. 349–50). I. Tragårdh (*loc. cit.*, pp. 203–14) has compared the advantages and disadvantages inherent to Berlese's and Tullgren's methods of automatic collecting for studying the fauna of the soil. A new, simple and satisfactory type of wooden olfactometer has been devised by N. E. McIndoo (*Jl. Agric. Res.*, **46**, 1933, 607–25). The success of this type was due to the ready response of blowflies to humid air currents. He has used this in an extensive series of experiments on the olfactory responses of blowflies, with and without antennæ. His conclusion is that the antennæ do not bear the olfactory organs.

ORTHOPTERA.—G. C. Crampton (*Jl. N. Y. Ent. Soc.*, **41**, 1933, 127–66) deals with the affinities of the archaic orthopteroid family Grylloblattidæ, and its position in the general phylogenetic scheme. E. M. Walker has followed his study of the head capsule and its appendages of *Grylloblatta* (*Ann. Ent. Soc. America*, **24**, 1931, 519–31) by a paper (*loc. cit.*, **26**, 1933, 309–44), in which he compares the head of this insect with those of other orthopteroid insects.

Research on the locust problem has made some big advances recently. A note has already appeared (SCIENCE PROGRESS, **28**, No. 110, 1933, 325–7) on a publication prepared by B. P. Uvarov dealing with the locust outbreak in Africa and Western Asia, 1925–31. In this connection it is pleasing to read (*Rept. Govt. Entomologist for the Year 1932*, Sudan Govt., Ent. Sect., *Bull. 36*, 1933) that H. H. King is carrying on with the experiment of dusting

flying locusts. This work was abandoned temporarily by the Sudan Government, but has been taken up by the Imperial Institute of Entomology in co-operation with the Colonial Office. Preliminary trials are to be made in England before putting the experiment to a practical field test Recent important papers on locusts include two by B. P. Uvarov; one (*Bull. Ent. Res.*, **24**, 1933, 407–18) describing the ecology of the Moroccan locust in Iraq and Syria and the prevention of its outbreaks, and the other (*loc. cit.*, pp. 419–20) giving some preliminary experiments on the annual cycle of the Red locust. J. C. Faure has followed up his brilliant research on locust phases in South Africa (*Bull. Ent. Res.*, **23**, 1932, 293–424) by an equally good piece of work (*Jl Econ. Ent.*, **26**, 1933, 706–18) on the phases of the Rocky mountain locust *Melanoplus mexicanus*. He has been able by experiments to transform *M. mexicanus*, the solitaria phase, into *M. spretus*, the phase gregaria.

COLEOPTERA.—F. G Holdaway and H. F. Smith (*Australian Jl. Expt. Biol.*, **11**, 1933, 35–43) have shown that the sex ratio in *Tribolium confusum* can be altered by the starvation of newly hatched larvæ. The changes in sex ratio observed cannot be explained on a basis of differential mortality and they are not progressive and proportional to the period of starvation. Further, with starvation for two or three days there is a preponderance of females. This discovery is of first-class importance.

The third of a series of studies on the structure of the larvæ of Hispine beetles by G. S. Maulik (*Proc. Zoo. Soc. London 1933*, 1933, 669–80) deals with the structure of the immature stages of the genus *Platyauchenia* and reveals the fact that the head, although of a true miner, does not show any of the types of structure previously recorded as belonging to a miner.

The larvæ of eight wood-boring Anobiidæ have been described by E. A. Parkin (*Bull. Ent. Res.*, **24**, 1933, 33–68). Keys are given for their separation, for use when either whole larvæ or mounted preparations are being examined.

LEPIDOPTERA.—P. Portier (*Lambillionea*, **32**, 1932, 157–64) has given a résumé of his study on the rôle of the wings and scales in the respiration and muscle activity of butterflies. By ingenious experiments such as greasing the wings, he has demonstrated that during flight the mechanism of the tracheal system alone is insufficient to supply the muscles with the large quantity of necessary oxygen. He has further shown that different parts of the wings, according to their degree of pigmentation, absorb calorific radiations unequally. This creates appreciable differences in temperature in different parts of the wing when exposed to the sun. The

result is the displacement of the fluids from one region of the wing to another, so giving rise to an air circulation in the peritracheal spaces. The sun in fact acts as a motor. Portier has shown that the scales are connected with the tracheal system in general and that during flight the air which comes into contact with the striated scales creates local disturbances resulting in aspiration by the scales. Thus the action of the sun and the anatomy and physiology of the scale system serve to augment the intensity of respiration during flight. A. Pictet (*loc. cit.*, pp. 182–7) has contributed a further paper on this subject and stresses the fact that the mechanism in butterflies at rest should be studied.

Following D. E. Minnich's experiments proving that certain butterflies respond to various substances when these come into contact with the mid and hind tarsi, H. Eltringham (*Trans. Roy. Ent. Soc. London*, **81**, 1933, 33–6) has discovered and described some sense organs, he has been able to find, on the tarsal joints of a male *Pyrameis atalanta*, and which he considers must be the chemo-receptors of the tarsi.

Some rather interesting results have been obtained by A. F. Satterthwait (*Jl. Agric. Res.*, **46**, 1933, 517–30) when studying the larval instars and feeding of *Agrotis ypsilon* Roth. Unseasonably cool weather, he concludes, may greatly retard larval development in the first instar and probably serves to increase the mortality rate in later stages of these larvæ. Another conclusion is that the feeding of larvæ which eventually yield females is appreciably heavier than that of larvæ which yield males and is lighter in the July than in the May brood. C. Hofmann (*Zeit. f. angew. Ent.*, **20**, 1933, 51–84) discusses the influence of starvation and restricted space on the growth and reproduction of *Arctia caja* L. and *Lymantria dispar* L. Mary Miles (*Ann. Appl. Biol.*, **20**, 1933, 297–307) from a study of growth in larvæ of *Plodia interpunctella* Hubn. has come to the conclusion that variation in the number of larval stadia, the rate of larval growth and the duration of larval life are the result of acceleration or retardation of physiological processes.

There are few, if any, instances of a complete biology of a Nepticulid having been published. In view of this, the description and biology by W. W. Jones (*Univ. Calif. Pub. Entom.*, **6**, 1933, 49–78) of *Nepticula braunella*, a species living on *Prunus*, is of particular interest.

HEMIPTERA.—W. E. Hoffmann (*Lingnan Sci. Jl.*, **12**, 1933, 97–128) has written a profusely illustrated account, with life history notes, of some Coreidæ from Kwangtung, China.

V. G. Deshpande (*Trans. Roy. Ent. Soc. London*, **81**, 1933, 117–32) has dealt with the anatomy of some British Aleurodidæ.

HYMENOPTERA.—Following a previous paper (1931) on the anatomy and histology of the alimentary canal in the common wasp, T. L. Green has now described the morphological changes in the gut of *Vespa* during metamorphosis and also the histological changes which occur in the mid-gut epithelium (*Proc. Zoo. Soc. London 1933*, 1933, 629–44).

An interesting biological study of *Sphex isodontia nigellus* F. Smith has been made by Le R. P. Octave Piel (*Ann. Soc. Ent. France*, **102**, 1933, 109–52).

Out of four species of parasites reared from the sugar cane borer (*Diatraea saccharalis*) in the United States, only one, the egg parasite *Trichogramma minutum*, occurs in large numbers. The introduction of additional parasites from South America was started in 1928. An account of the biology and collection of these parasites and their shipment from Peru and Argentina is given by H. A. Jaynes (*U S. Dept. Agric., Tech. Bull 363*, 1933). The most important larval parasite was found to be *Parathesia claripalpis* Van der Wulp, a Dexiid fly. An account of the parasites of *Coleophora laricella*, the larch case-bearer, has been written by W. H. Thorpe (*Bull. Ent. Res.*, **24**, 1933, 271–91).

D. L. Parker (*Jl. Agric. Res.*, **46**, 1933, 23–34) has come to the conclusion, after some experimental work, that there is little serious competition between the two Hymenopterous egg parasites, *Anastatus disparis* Ruschka and *Ooencyrtus kuvanæ* Howard, of the gipsy moth. In other words it is advantageous to have both parasites in the same locality.

A useful list of the Hymenopterous parasites of the Coccidæ, etc., in Hawaii has been compiled by D. T. Fullaway (*Proc. Haw. Ent. Soc.*, **8**, 1932, 111–20).

A. C. Evans (*Bull. Ent. Res.*, **24**, 1933, 385–405) has described the biology and larval morphology of three Alysiine Braconids and one Chalcid parasite of the pre-imaginal stages of some carrion-infesting Dipterous larvæ, while R. A. Roberts (*U.S. Dept. Agric., Tech. Bull. 365*, 1933) has described the biology of *Brachymeria fonscolombei* Dufour, an Hymenopterous parasite of blowfly larvæ.

DIPTERA.—E. G. Gibbins (*Trans. Roy. Ent. Soc. London*, **81**, 1933, 37–51) has made a thorough study of an Ethiopian Simulid, *Simulium damnosum* Theo., which is a troublesome biting insect in certain parts of tropical Africa. The larva, pupa and adults of both sexes are described and figured. The third of a series of papers by H. F. Barnes dealing with zoophagous gall midges of the world

has now appeared (*Bull. Ent. Res.*, **24**, 1933, 215–28). In this the gall midges which attack mites are considered.

The carnivorous habit of certain Mycetophilid larvæ has received but little attention. Recently G H. Mansbridge (*Trans. Roy. Soc. Ent. London*, **81**, 1933, 75–92) has made a study of the biology of some Ceroplatinæ and Macrocerinæ which includes an appendix by H. W. Buxton on the chemical nature of the larval web fluid. In this it is shown that the larvæ of three species of *Platyura* and one species of *Apemon* are predaceous, catching their prey by entangling them in their webs. The droplets of fluid in the web are shown to contain oxalic acid sufficiently strong to kill insects coming in contact with it. The larvæ of *Platyura* were immune to this acid and resistant to other acids. The prey of the *Platyura* found in the field included Oligochætes, Collembola and Dipterous larvæ (*Miastor* sp. and Cyclorraph spp). Under laboratory conditions they accepted the larvæ of *Piophila casei* (Diptera), of *Scolytus intricatus* (Coleoptera), of a Scarabæid (½ inch long) as well as *Anurida* sp. (Collembola) and free living Nematodes (¼ inch long).

The morphology and biology of a cambium miner (Agromyzidæ) of willows has been studied by H. F. Barnes (*Ann. Appl. Biol.*, **20**, 1933, 498–519). There are relatively few cambium mining insects, and it is noteworthy that the larvæ of the fly under consideration exhibited the calcospherites which are so typical of the Agromyzidæ in general.

The life history of *Onesia accepta* Mall., which is parasitic on the earthworm, *Microscolex dubius* Fletcher, has been described by Mary E. Fuller (*Parasitology*, **25**, 1933, 342–52) as well as the external morphology of the three larval instars and puparium. This is the first time the complete life history of this fly has been traced. Keilin, however, has worked out the life history of *Pollenia rudis*, another fly which is parasitic on earthworms. *O. accepta* is larviparous and contains up to 550 larvæ in various stages of development It was found that living worm tissue was essential to the first- and second-stage larvæ, but that in the third stage the larvæ could feed on dead and even putrid worms.

In an anatomical and experimental study of the photoreceptive organs of the larval *Lucilia sericata*, J. K. Ellsworth (*Ann. Ent. Soc. America*, **26**, 1933, 203–16) has shown that protection from overstimulation by light is accomplished through the retraction of the entire photoreceptive organ, which is further protected by the infolding of the chitinous collar. Each organ consists of a biconvex lens, a pre-retinal membrane, a fasciculus of fibrils, retinal cells and a nerve bundle and is apparently devoid of pigment. C. E.

Abbot (*Psyche*, **39**, 1932, 145–9) has shown that it is only at the temperature of metabolic optimum that humidity has much effect on the olfactory responses of blowflies. At that temperature the optimum for the humidity is 73 per cent. Some rather amazing figures for the numbers of eggs laid by blowflies occur in a paper on nutritional requirements and fecundity by M. J. Mackerras (*Bull. Ent. Res.*, **24**, 1933, 353–62). For example 3,171 eggs were laid by a hybrid *Lucilia* fly which lived 94 days and 2,373 eggs were derived from a single *L. sericata* which lived 77 days.

An interesting account, with references, of the use of blowfly larvæ in the treatment of infected wounds has been written by W. Robinson (*Ann. Ent. Soc. America*, **26**, 1933, 270–6). The activities of blowflies and associated insects have been studied by means of bait traps placed at various heights (ground level, 15 ft., 30 ft. and 45 ft up) by R. A. Roberts (*Ecology*, **14**, 1933, 306–14). The flies were fairly evenly distributed between the four elevations, and it is suggested that the activity of predatory beetles in the two lowest baits prevented the percentage of flies from being greater at these situations. The numbers of the most abundant parasite increased with increased height, while the most important beetle predator of the blowflies was chiefly (79·6 per cent) on the ground and just over 8 per cent. at 45 feet. M. J Mackerras and M. R. Freney (*Jl. Exp. Biol.*, **10**, 1933, 237–46) have given the results of work specifically designed to elucidate the relation of larvæ of Australian blowflies to living sheep. The *in vitro* experiments are dealt with in this paper.

The second part of T. A. M. Nash's account of the ecology of *Glossina morsitans* (*Bull. Ent. Res.*, **24**, 1933, 163–95) has now been published. He suggests that mass attacks upon the fly by liberating *Syntomosphyrum glossinæ* might be successfully used in districts where tsetse breed in humus. Puparia log traps, constructed so that puparia deposited beneath them can be easily destroyed by exposure to the midday sun, are also suggested. C. H. Chorley (*loc. cit.*, pp. 315–18) has described some traps of the "crinoline" and "ventilator" forms for tsetse flies.

Other Orders.—J. Davidson (*Australian Jl. Expt. Biol.*, **11**, 1933, 9–23 and 59–66) has given further results of his investigations on *Sminthurus viridis*. In the first paper he has dealt with factors affecting the development and hatching of the eggs, namely temperature and moisture, and the results of experiments with eggs incubated under different moisture conditions are presented. In the second contribution he deals with its distribution in South Australia, which can be determined by the mean monthly rainfall

and evaporation. A full account of the Hawaiian Collembola by J. W. Folsom (*Proc. Haw. Ent. Soc.*, 8, 1932, 51–92) has recently appeared as well as a preliminary list of British Collembola by F. A. Turk (*Trans. Ent. Soc. South England*, 8, 1933, 92–7).

AGRICULTURAL PHYSIOLOGY. By ARTHUR WALTON, B.Sc., Ph.D., School of Agriculture, Cambridge.

MILK SECRETION.—A recent review of the physiology of the mammary glands by C. W. Turner appears in an important composite work, *Sex and Internal Secretions*, edited by Allen (Baillière, Tindall & Cox, London, 1932). The review contains some original unpublished research. Discussing the general relation of the mammary gland to the organism the writer points out that it is of prime importance for the young of mammals that secretory activity of the mammary gland should coincide with birth and early extra-uterine life. This synchronisation was early shown by transplantation experiments to depend not upon direct nervous co-ordination but upon some humoral mechanism. Since removal of the ovaries resulted in the involution of the mammary gland, and since replacement of the ovaries by grafting led to a resumption of normal activity, it was clear that the ovaries were intimately concerned. More recent research demonstrates however that the mechanism is by no means simple and that in addition to the ovary, the anterior lobe of the pituitary plays an important part.

The development of the mammary gland can be divided into several stages. In the embryo there is formation of the teat, milk cistern and primary ducts. This stage of development is not sex-specific and may occur equally in both male and female. Until puberty there is little change, but at this time, in the female, considerable growth of the duct system is brought about by the ovarian hormone "œstrin." This development can be produced experimentally in the castrate by injecting œstrin. The development obtainable at this stage is however incomplete and except to a slight extent in some animals, does not result in lobule formation or active secretion. Since during pregnancy and pseudo-pregnancy there is rapid hyperplasia of the lobules it was thought that a functional relationship existed between this development and the corpus luteum. However, extracts of the corpus luteum failed to produce any effect when injected into the castrate. When, however, œstrin and corpus-luteum extract were given together, hyperplasia of the gland lobules equivalent to that of the first half of pregnancy was produced. During the second half of pregnancy changes in the gland are characterised by enlargement of the epithelial cells and

the initiation of secretory activity. This latter phase is apparently dependent on the hormone or hormones of the anterior lobe of the pituitary and can be produced experimentally by injection of extracts, but it would also appear that there are distinct species differences in the extent to which the action of the hormones is dependent upon previous development of the lobules under ovarian influence and the extent to which other hormones (œstrin or corpus-luteum hormone) are required.

Pregnancy Diagnosis.—A simple, rapid and accurate test of pregnancy has long been desired in human clinical practice, and a similar test applicable to the domesticated animals would have considerable economic value. The breeder may want to know at the earliest possible date whether his mare or cow is pregnant to a particular service, so that he may dispense with further trials or services ; he may wish to know without delay whether a particular sire is fertile, or he may wish to know whether the constant recurrence of œstrus after service is due to sterility and failure of fertilisation or to early abortion of the fœtus. To be of value the test must be inexpensive and the preliminary part at least should be capable of being carried out by the breeder or by a veterinary surgeon without elaborate laboratory equipment. It is essential that the test should be applicable to early stages before pregnancy can be diagnosed by palpation.

Certain chemical tests have been tried. Those of Abderhalden and Manoilov depended upon certain obscure serum reactions, but were unreliable. In 1927 Ascheim and Zondek investigated the hormone content of pregnancy urine and since then several reliable tests for the human have been developed. The "Ascheim and Zondek" test depends upon the presence, in the blood or urine of pregnant women, of substances similar in properties, if not identical, to the hormones of the anterior lobe of the pituitary. When injected into the immature rat or mouse they cause premature development of the ovaries with growth of follicles and formation of luteal tissue or "blood points." Pregnancy can be detected almost as soon as the first menstrual period is missed. With modifications of the test an accuracy approaching 100 per cent. has been claimed and the test completed within 48 hours. The "Friedman" test depends similarly upon ovarian stimulation, but in this case injection is made intravenously into a mature female rabbit and a positive reaction is recorded if on autopsy 24 hours later freshly formed corpora lutea are present. Another important test ("œstrin" test) consists of the detection of œstrin in increased amount in the blood or urine. The presence of œstrin is demon-

strated by injection into castrated female rats or mice and the subsequent appearance of a typical œstrous smear from the vagina.

Unfortunately the application of these tests to the domesticated animals has been disappointing. Cole and Hart (*Amer. J. Physiol.*, **93**, 1930) found ovary-stimulating substances in the serum of pregnant mares but not before about the 40th day, and œstrin in the urine about the 60th day. Crew, Miller, and Anderson (*Vet. J.*, **87**, 1931) reported œstrin as present in significantly increased amount from about the 20th day and considered that the test might have some considerable value. Kust (*Zuchtungskunde*, **7**, 1932) found œstrin in increased amount in the urine of mares in the 7th–8th week. In the cow the tests have been even less satisfactory from a diagnostic standpoint. Turner, Frank, Lomas and Nibler (*Missouri Ag. Exp. Sta. Res. Bull* 150, 1930) found a positive increase in œstrin on the 70th–100th day of pregnancy. Leonard (*Amer. J. Physiol.*, **98**, 1931) could detect no ovary stimulating substances in the urine, and Asdell and Madsen (*Cornell Vet.*, **23**, 1933) obtained negative results with tests applied to both urine and serum. Pigs, goats and sheep have been tried also but without significant result. It would appear therefore that with the possible exception of the horse, the hormone tests of pregnancy, which have proved so satisfactory in the case of the human, are either inapplicable or require further technical improvement to be of practical diagnostic value.

In 1925 Woodman and Hammond (*J. Agr. Sci.*, **15**, 1925) described the physical and chemical changes in the cervical mucus of the cow which take place during the œstrous cycle and pregnancy. During pregnancy the mucus becomes thick and "rubbery." A similar change is seen in the cervical mucus of the mare. Nikitin (*Probl. Zhivotn.* **9–10**, 1932) describes a paper by Kurosawa (*Tierarztl. Rundsch.*, **20** and **21**, 1931) in which the claim is made that by examination of the cervical mucus of the mare, diagnosis of pregnancy can be made with considerable accuracy as early as the 10th day after service and after the 20th day with certainty. Confirmation of these results would be valuable, for undoubtedly they offer great possibilities.

ARCHÆOLOGY. By E. N. FALLAIZE.

EARLY MAN IN EAST AFRICA.—The event of outstanding interest in the study of early man during the last six months has been Dr. L. S. B. Leakey's report on the human remains discovered by him in the fossil deposits at Kanam and Kanjera at the north-east corner of Lake Victoria Nyanza, which was presented at a meeting

of the Royal Anthropological Institute on October 20. Since the conference at Cambridge in March last (see SCIENCE PROGRESS, vol. XXVIII, p. 141) Dr. Leakey has been engaged in the comparative study of the Kanam jaw and the reconstructed skulls from Kanjera. Briefly his conclusions are as follows:—The Kanam jaw, of early Pleistocene or even possibly of Pliocene age, has been shown by an X-ray examination of the roots of the molars and premolars to be sufficiently distinct from *Homo sapiens* in respect of this character to warrant its being regarded as a new species. In respect of other characters, however, its retention within the genus *Homo* is justified. It has a prominent chin and the teeth in size and in arrangement in the dental arch resemble those of "modern" man. It represents a race ancestral to *Homo sapiens*, which it is proposed to differentiate as *Homo Kanamensis*.

The Kanjera skulls, of middle Pleistocene age, represent an advance on the Kanam race. They are thicker and lower in relation to their length than typical skulls of *Homo sapiens*; but nevertheless they are to be regarded as generalised and primitive examples of "modern" man. The eyebrow ridges are not prominent. The fragment of femur associated with the cranial remains indicates considerable muscular development and points to an upright gait.

In his report Dr. Leakey went on to draw certain conclusions from the occurrence of a rude shipped pebble industry with the Kanam jaw and of a developed handaxe industry with the Kanjara skulls. Not only does this association lend support to the view which relates the development of a core type of stone implement with *Homo sapiens*, and a flake implement with *Homo Neanderthalensis*, but taken in conjunction with the occurrence of a complete developmental series of core implements in the Oldoway deposits of Tanganyika, it suggests, he holds, that East Africa may be very near the centre of the development of the handaxe culture, if it be not the actual centre itself.

RACIAL DISTRIBUTIONS AND ARCHÆOLOGY.—A feature of unique interest in Dr. Leakey's interpretation of his recent discoveries in East Africa is the close association of a developmental series in a Stone Age industry with human remains in which the differences point to an evolutionary progression. It affords direct evidence for a correlation of racial differentiation and cultural advance such as is attempted inferentially by Professor H. J. Fleure in a recently published address on "Racial Distribution in the light of Archæology" (*Bulletin of the John Rylands Library*, **17**, No. 2) in which he links the data of archæology, race-study and sociological research.

The argument is too long and detailed to admit of an adequate summary here ; but in its broad outlines it shows how the spreads of race types have some measure of correspondence with the spreads of social and cultural schemes. Professor Fleure begins by pointing to the early differentiation between *Homo sapiens* and Neanderthal man (as indicated by Dr. Leakey's discoveries in East Africa), and to the associated of the former with the development of the core type of stone implement, originating in all probability in Africa, while the latter, who has what is essentially an Eurasiatic distribution, is associated with the flake implement. Food gathering and hunting, which by inference are regarded as the characteristic activities of early man, are found among existing races in either the tropical forests or in marginal areas such as Australia, South Africa and the Arctic, *i.e.* among the pygmies of Africa and south-east Asia, the Bushmen, the jungle tribes of India and south-east Asia, the Australians, the extinct Tasmanians, and the Eskimo. These, therefore, may be taken to represent early drifts of *Homo sapiens*. Herding, the outgrowth of the man's occupation in hunting, and cultivation, developing out of the woman's work of food-gathering, and originating near the great rivers of north-east Africa and south-western Asia, and possibly in India, were carried by long-headed peoples to the north-west into Europe and to the south in Africa and Asia, extending in the latter to the south-east as far as New Guinea. Progress southward was accompanied by an increasing infusion of pygmy blood and the growing importance of an archaic type of culture. An extension north-eastward associated with a late Caspian or Tardenoisian culture would account for the early drift of peoples to north-east Asia and its extension to America.

North of the region of early cultures and drifts the central mountain zone of Asia, Anatolia and Europe is the home and line of migration of the broad-headed races, the Alpine, Armenoid and Asiatic brachycephals, of which the western extension had reached Europe in late palæolithic times and by the beginning of the Bronze Age was established as the peasant population of Central Europe. This movement, however, had found already existing in the western Asiatic and south Russian steppes a long-headed race, which later, in the late Bronze and early Iron Ages, irrupted into Central Europe and reached as far as India, becoming the originators and carriers of the Aryan languages. The dry climatic conditions which were the causes of these movements were probably also responsible for the fact that the Bronze Age cultures and peoples left Africa south of the Sahara practically untouched. Professor Fleure goes on to

deal with other racial movements such as those into America and the Pacific, which need not be followed here. Enough has been said to indicate how far this tentative correlation of archæological and ethnological evidence carries him in accounting for racial distributions.

In this connection attention may be called to a series of lectures on " Environment and Race " broadcast by Professor Griffith Taylor from the University of Chicago throughout the autumn session, in which a similar use is made of archæological data in elucidating points of obscurity in racial distribution, but at the same time more stress is laid on the influence of environment in racial differentiation. Professor Taylor adopts the view that the races of the world are arranged in five zones about central Asia, these zones being " stratified " in evolution and culture. The five major races thus distinguished are the Pygmy or Negrito, the Negro, the Australoid, the Mediterranean and the Alpine. It is argued that they evolved in Central Asia while the four Ice Ages were operating, each race evolving during the 100,000 years of each Ice Age, and being driven out by the subsequent glaciation. Hence the " stratification " of races and cultures.

A syllabus of the lectures *An Atlas of Environment and Race*, containing a very full statement of the argument and over a hundred distribution maps, is published by the University of Chicago Bookshop, price 40 cents.

THE MEDITERRANEAN RACE IN INDIA.—A suggestion put forward by Professor Griffith Taylor is that certain resemblances, which have been noted in the cultures of Melanesia and ancient Egypt, are due not to " diffusion," but to the common racial origin of the peoples of the two areas. In his distribution maps he makes the cultures common to the Mediterranean Race extend from western Europe to New Zealand, the extension to the latter running from Melanesia alongside the eastern coast of Australia. Since the discovery of the prehistoric culture of the Indus Valley at Mohenjodaro and Harappa, the question of the extension of early Mediterranean culture and its relation to that of the Middle East has become increasingly important in its bearing on the ethnic affinities of the early populations of India. Of recent work bearing on this point among the more important is a communication presented to the Anthropological Section of the British Association at the Leicester meeting by Professor Gordon Childe which dealt with the affinities of painted potteries from India and Iran. He pointed out that the painted pottery of the Indus civilisation from Amri on the lower Indus at least as far as Harappa on the Ravi 500 miles away

was astonishingly uniform and at the same time highly sophisticated. Its individuality is expressed in a self-conscious style, the distinguishing peculiarity of which is a free use of repetition motives (*i.e.* motives which can be repeated indefinitely in any direction) such as finds no parallel in the third millennium or earlier, except perhaps in Crete. In Baluchistan and Waziristan there are a number of barbaric ceramic groups which are obviously related to one another and to the Indus ware in the motives employed. Funerary ware closely allied to that found at Susa I, al'Ubaid and Samarra reveal that here is an extension eastward of Frankfort's "Highland" culture in a very pure form, and as this connection cannot be earlier than the third millennium and must be later than or partly contemporary with the Indus culture, it demonstrates that the direction of the spread is eastward and not *vice versa.* Pottery from Nal and Nundara in Baluchistan, though in time probably contemporary with the Indus black-on-red wares, may be regarded as a development from the Amri wares of lower Sind which are older than the classical Indus wares, and in turn have affinities with the Jemdet Nasr wares of Mesopotamia. A summary of Prof. Childe's paper appears in *Nature*, Nov. 18, p. 790, and the ceramic types are analysed and figured in *Ancient Egypt*, 1933, I–II, pp. 15–25.

Professor Childe's brilliant, though necessarily highly technical analysis of the affinities of the ceramics of the Indus Valley civilisation, linking India, Baluchistan, Iran, and Mesopotamia, and suggesting a connection with far-distant Crete, makes an assured beginning in a scientific understanding of the history of cultural movement in the Middle East during pre- and proto-historic times. How far-reaching these investigations may become ultimately is foreshadowed by results such as those obtained by Mr. M. E. L. Mallowan at Arpachiyah on behalf of the British School of Archæology in Iraq. The finds at Arpachiyah not only afford a link between northern Mesopotamia and Baluchistan (see SCIENCE PROGRESS, vol. XXVIII, p. 138), but in the later stages of the excavation, when virgin soil was reached, they demonstrate in the painted pottery, the essential homogeneity of Mesopotamian culture in its early stages, and also look towards Crete and the Mediterranean.

How wide are the ramifications and the implications of the discoveries of the Indus Valley may be gauged in the chapters on race, language and religion which Dr. J. H. Hutton, as Census Commissioner for India, contributes to his report in Part I, vol. I, of *The Census of India, 1931*, which has recently been published. Dr. Hutton points out that it is no longer possible to hold the

orthodox view of the history of race and culture in India in the form in which it was put forward by Sir Herbert Risley in 1901. It now seems probable that there has been a far greater continuity in the prehistory of India than was then supposed, and that it was not characterised by cultural and racial isolation. Dr. Hutton, analysing the religious beliefs of India on an ethnic basis, suggests a sequence to account for the elements, obviously of very diverse origin, which can be differentiated in Hinduism. The Negritos, the first occupants of India, contributed a reverence for the pipal tree and possibly a phallic cult, which may have been perpetuated by the next comers, the Proto-Australoids, who probably contributed the totemic theory. The Mediterraneans contributed a phallic cult, a megalithic culture and the life-essence theory. Omitting here the position of the Mundas which is obscure, it is possible that the development of the life essence theory into reincarnation is to be attributed also to the Mediterraneans, as well as the worship of the Great Mother; while from Asia Minor via Mesopotamia, came religious elements, which superseded the fertility and soul-matter cult by one of personified deities, sacrificial propitiation and a formalised worship. This also included phallic elements and such institutions as the *devadasi*, astronomical lore, the cult of the heavenly bodies and the priestly institutions which formed the basis of modern Hinduism, of which the final form was determined by the conflict of this proto-Hinduism with the imported religion of the Aryan invaders.

The discoveries at Mohenjo-daro, Dr. Hutton points out, have made it very doubtful that the generally accepted theory of Hindu society and religion as imposed by Aryan invaders can any longer be held. The pre-Aryan religion of the Indus Valley, the finds have shown, involved a cult of a bull and of the snake—typical Mediterranean cults to be found in Crete—and also of phallic symbols including "ring" and bætylic stones, probably all part of the soul-fertility cult, which is associated throughout India with menhirs, dolmens and a megalithic culture generally. Indeed the megalithic Mycenæan theatre has been connected with India and so with the far east and the Pacific Islands. It is therefore suggested that while society in India was, or aimed at being Aryan, its religion was older than the so-called Aryan invasion. It is, as might be expected, not in the Punjab, where the Aryan invaders were strongest, that the historical Hindu religion first appears, but to the east, where fusion between the invaders and the previous inhabitants took place. It is clear that the previous inhabitants of India lived in cities and had a high civilisation, and it is significant that

Hinduism is remarkable for the number of similarities of its tenets and practice with those of Asia Minor and Mesopotamia. The important position of Shiva, Vishnu and Kali as compared with that of Indra, the Aryan deity, signifies the triumph of the old gods over that ot the invader. Dr. Hutton also points out that the deification of kings typical of the Hindu attitude to kingship is stated by Langdon to be characteristic of Sumerian religion, as contrasted with Semitic, while it is not characteristic of the Rigveda. Ancestor worship again is strong in India but is foreign to northern European religions. We need not pursue Dr. Hutton's argument further. He associates the elements mentioned and others with the Dravidians who, it is thought by some at least, are to be held responsible for or to be associated with the civilisation of the Indus Valley.

In another connection Dr. Hutton points out that the general parallel between the southern Indian custom of dedicating girls in the temples of the god who are known as *devadasi* and practically, though not necessarily, serve as temple prostitutes, and the custom mentioned by Herodotus at the temple of Mylitta at Babylon, with analogous customs in Syria and Asia Minor, and extending in the Mediterranean as far as Carthage and Cyprus where it links up with Crete and Mycenæ, affords another link between the Dravidians and the early Mediterranean.

In brief, Dr. Hutton's view is that, following on the Proto-Australoids, whose origin is probably to be sought in Palestine, there were two waves of migration, of which the first was a primitive people speaking an agglutinative tongue from which the Austro-Asiatic languages are derived and the second, much later, was of a very advanced Dravidian-speaking people of the same ethnic stock with a slight Armenoid admixture. These were the authors of the Mohenjo-daro civilisation. In the west in the third millennium B.C. this civilisation was flooded by an immigration from the Iranian plateau and the Pamirs of a brachycephalic race speaking an Aryan language of the Dardic type. Finally, about 1500 B.C., came the Indo-Aryan migration into the Punjab, which first occupied the area between the Indus and the Jamna and later sent colonies across the Jamna into Hindustan.

On the other hand, Sir Edward Gait, in the course of a communication presented to the Geographical Section of the British Association at the Leicester meeting (see *J. R. Society of Arts*, Oct. 20, 1933, **81**, 1065–72) on "The Races and Languages of India," points out that there are certain difficulties which stand in the way of the acceptance of these theories, and notes that there

is for instance little definite evidence that the Dravidian languages have Mesopotamian and Caucasian affinities, as Dr. Hutton's theories require, or that the Austro-Asiatic languages are allied to Sumerian; while there is nothing at all to show that the Alpine invaders had adopted an Aryan form of speech before they came to India.

NOTES

Post-glacial Geology (T. W. W.)

In the *Transactions of the Northern Naturalists' Union*, vol. I, Part 2, Dr A. Rastrick and Dr. Kate Blackburn publish the third contribution on "The Late Glacial and Post-Glacial peats in the drainage area of the Tyne and part of the coastal plain of Northumberland." The area chosen provides a great variety of physical and climatic conditions and five types of peat deposits are described, together with the plant remains found in them. Pollen diagrams are given from the following sites ·

Fell Top Peats :	Mickle Fell (2,300 ft.), Killhope Moor (2,050 ft.), Barden Fell (1,460 ft.).
Valley Head Peats	Waskerley (1,070 ft.).
Channel Peats :	Catton Carr (1,020 ft.), Colt Cragg Moss (680 ft.).
Lowland Pond Peats :	Prestwick Carr (170 ft.), Newbiggin Carr (30 ft.).
Shore Peats :	at or just below sea level revealed by sea erosion or in river estuaries.

From these studies the following conclusions were drawn. On the retreat of the ice an Arctic flora of fairly wide extent spread over the higher summits, but later suffered much denudation and erosion. In Boreal time peats formed in the valley heads which contain pine, hazel and some birch. With a change of conditions in lower-Atlantic time, birch-hazel scrub extended over most of the hill-slopes and on to the fell-tops, and pine almost but not quite disappeared. By middle-Atlantic time, the birch scrub period passed and the fell tops were occupied by cottongrass and *Sphagnum* peat, but alder and birch-hazel woods occupied the better drained slopes.

On the coast some of the higher headlands were used by mesolithic man as flint-chipping sites, while in other parts true pine forests were established on the weathered boulder clay. The low-level peat areas all pass in Atlantic time into normal peaty mosses of cottongrass and *Sphagnum* or *Hypnum* ; the trees here are largely birch and alder with a small amount of pine, also oak, lime and elm.

Beech is recorded as rare. The sand-dune belt, that in many places covers the shore peats, was probably initiated towards the end of Atlantic time and mainly built up in the warm, dry Sub-Boreal period. In this drier Sub-Boreal period the upland peats were partially dried and heather grew freely upon them and conditions favourable for the preservation of pollen ceased. The return to wet conditions in Sub-Atlantic time initiated many of the present wet bogs and mosses, based on the older peats, but containing little or no tree pollen

Barley Research (E. J. S.)

A Supplement to the *Journal of the Institute of Brewing* (vol. XXXIX, No. 7, 1933, pp. 287–421) presents a report by Sir John Russell and L. R. Bishop on the investigations on Barley carried out during the past ten years under the Institute of Brewing Research Scheme. One of the most important of the results obtained concerns the nitrogenous compounds present in the barley grain. It appears that the proportion of the different nitrogen compounds is dependent upon the total nitrogen content, so that for a given variety, if the total nitrogen content be known, the proportions in which the various components are present can be calculated with a considerable degree of accuracy. Further this generalisation appears to be independent of the factors which determine the total nitrogen content ; a high value, whether the outcome of climatic or edaphic factors, or the result of manurial treatment, showing the same relations between the constituents. With an increase of nitrogen content the proportion of hordein increases, whereas the proportion of salt-soluble nitrogen decreases with increase of the total nitrogen.

Field experiments have shown that climatic factors and soil conditions affect the nitrogen content most profoundly, though manurial treatment and the variety grown also play a part. Of these factors the rainfall during the months of April, May and June exercises so marked an influence that, on a knowledge of this alone, the nitrogen content can be predicted with a considerable degree of accuracy. Since the most important characteristics of barley from the commercial standpoint are the degree of maturation and the nitrogen content, the importance of these results is obvious.

Barley will not tolerate acidity of the soil and suffers more readily from this cause than any other cereal crop. The best-quality barley as well as the worst has been grown on sand, but, in general, medium and light loams yield the best average quality. The highest nitrogen contents recorded were in barleys from sands and fens, whilst the lowest were found in barley grown on chalk.

The brewers' extract from barley decreases as the nitrogen content rises and this was found to be true of all the varieties tested. Further, the relation between the different varieties in this respect is maintained, alike when climatic conditions have resulted in a low or in a high nitrogen content. Interesting biochemical differences have been found between the two-rowed and six-rowed barleys. The latter yield a lower proportion of soluble nitrogen, but show a wider range in carbohydrate content and hence in extract. The phosphorous content of barley which occurs in the form of the phosphoric ester of inosite might be expected to affect the brewing qualities, but in actual fact this constituent is found to vary only to a very slight degree.

A comparatively small amount of data is at present available with regard to the relation between the chemical composition of barley and the quality of the beer which it yields. These data do, however, appear to indicate that barleys of high nitrogen content produce beers which are better flavoured at first, but deteriorate on storage, whereas barleys of low nitrogen content yield beers which, though inferior when brewed, attain ultimately a better flavour.

Whilst the authors state that there is "the hope and possibility" that a good deal of the imported malting barley could be grown in this country, yet the investigations show that the climatic factor is an important one. British barley usually has to be kiln dried, containing as it does from 15 to 18 per cent. water, as compared with from 10 to 12 per cent. in Californian barley. This and certain other practical advantages claimed for the imported barleys imply a restricted demand, so that to attempt anything in this country approaching over-production is, as the authors wisely emphasise, only courting disappointment.

Industrial Research and the Progress of Science (M. S.)

That the rare metal or element of yesterday often becomes the commonest of industrial materials of to-day has been shown by the rapid rise of aluminium to a position of supreme importance. While the essential properties of such elements are usually worked upon and published by the personnel of academic laboratories, we are apt to ignore the contributions to the world's wealth of knowledge rendered by those who maintain research workers in industrial laboratories. And it is very often the case that publications from such concerns are more up to date and furnish our students with a clearer insight regarding the present position of knowledge and future possibilities of the rarer metals than do our text-books.

A remarkable example of such fostering of interest in the elements tantalum, tungsten, and molybdenum, is a booklet summarising the activities of the Fansteel Products Company of America. Whereas tantalum is referred to in texts as a very rare metal with little application in industry apart from a minor use in chemical laboratory ware, we find that the metal in practice is being widely adopted by the more progressive manufacturers of radio valves for plates and grids. The element has long been known for its power of occlusion of gases, this fact explaining its appearance in wireless valves ; and since the price of tantalum has already fallen to one-fifteenth of that of platinum, it is not surprising to learn that an all-tantalum valve is attracting the attention of research workers in America. In the chemical laboratories in England, at any rate, the value of tantalum dishes, filter cones, spatulas, etc., is not yet appreciated. Although the metal does not possess the inertness of platinum with regard to oxygen above 600° C., it is unaffected at temperatures up to this point, while in its resistance to aqua regia, its greater durability and hardness, and its low cost, it is superior. In electrochemical analysis there are further advantages to record. Zinc may be deposited on tantalum since it does not alloy with it ; gold and platinum may be deposited and then dissolved off with aqua regia ; and indeed, provided the tantalum be kept away from hydrofluoric acid, the metal fully justifies its name of "the everlasting metal." It is also recorded that experiments carried out by the Bureau International des Poids et Mesures in France have shown that tantalum is equal to platinum or platinum-iridium in the making of analytical weights.

Molybdenum and tungsten also claim attention, the latter having the highest melting point of any metal. It is a general idea that tungsten is used solely for lamp filaments and for steel production, its present wide use in the construction of electrical contact points being little known. Silver, platinum, and platinum alloys were formerly the chief metals for this type of usage ; but tungsten is low in cost, its melting point (3,370° C.) is twice as high and its hardness three times that of platinum. Molybdenum wire is a valuable material for heating elements in electric furnaces. In the Fansteel laboratories a large amount of valuable research work has been carried out in this direction, and many of the most recent constants for the above three metals, together with their essential properties, are summarised in the booklet referred to ; furthermore, the photographs of the processing of these metals are superior to those in our metallurgical texts.

Post Office Research (S. K. L.)

The new Post Office Research Station at Dollis Hill, London, N.W.2, was opened by the Prime Minister on October 23. A description of the station and an account of its research programme appeared in the *Electrician* for October 27 and November 3. The research block of the building is rectangular with end wings, and has three stories with an attic. There is a central block with a number of independent laboratories behind the main block. The purpose of the Research Station is not only to develop and study basic principles of electrical communication and any problems arising in the telegraph and telephone services, but to provide intensive instruction to new entrants.

The station is divided into several laboratories: the General Electric Laboratory, the Metallograph Laboratory, the Spectrograph Laboratory, Physics Laboratory, Photometer Laboratory, High Voltage Annexe, Signalling Apparatus and Circuits Laboratory, Radio Laboratories, Speech Tests Laboratories, Life Tests Laboratory, Telephone Instrument Testing Laboratory, Valve Testing Laboratory, Line Transmission General Laboratory, Cable Research Laboratories, Mechanical Testing Laboratory, and Laboratories for Chemistry, Acoustics, and Durability. There is a lecture hall, equipped with a sound film projector, and a library. The training school is in a separate building. In the rear are the workshops, and beyond is an open space devoted to research and training in connection with external plant.

Recent developments by the Research Staff of the Post Office include a new type of echo suppressor for use in long-distance telephone circuits, superior to the earlier type and much cheaper, a simple and cheap carrier current telephone equipment, and a device for the bulk testing of telephone transmitters and receivers, in which speech is closely imitated by electro-mechanical means.

For the benefit of the telephone subscriber, three types of microphone and loudspeaker equipment have been developed. The first uses an ordinary transmitter but a loudspeaker is substituted for the ear-piece. A second type employs a loudspeaker and a special microphone which may be two or three feet away from the user. This type is suitable only for short lines, but a third type includes a further device using gasfilled relays so that it may operate over any telephone line. Each type requires a local amplifier fed from supply mains, the switching being controlled by the telephone switchhook and loudspeaker volume control.

Telegraphy systems for text and picture transmission have been studied from the point of view of distortion, a subject which until

recently has been neglected. Distortion measurement is of paramount importance since machine telegraph systems are critically dependent on the accuracy and timing of the received signals.

The problem of eliminating interference with broadcast reception is also being actively studied.

Cathode-ray Television (S. K. L.)

A most ingenious television system in which cathode-ray tubes are used in the transmitter and the receiver to the complete exclusion of all moving mechanical parts, is described by V. K. Zworykin in the *Journal of the I.E.E.* for October.

The device of greatest interest is the transmitting cathode-ray tube, which is a true electric eye, and is known as the "iconoscope." Inside the tube is a large photo-electric surface of a unique character. Unlike the usual photo-electric cell, the sensitive metal film is not continuous but consists of a conglomeration of minute spots or globules, a mosaic in fact, deposited on a thin sheet of dielectric such as mica, backed by a metal plate which is connected to a valve amplifier. This arrangement consists, in effect, of vast numbers of microscopic photo-electric cells in series with a small capacity to a common conductor. Light from the scene to be transmitted illuminates this sensitised surface exactly as in an ordinary camera and each miniature element acquires a positive charge by the emission of photo-electrons, the magnitude of the charge being a function of the light intensity. The surface is scanned in "saw-tooth" fashion many times each second by the beam of cathode-rays from the "electron gun" by means of deflecting coils, and as the "spot" of the beam crosses the charged photo-elements, the charges disappear on account of the electrons in the beam. The resultant sudden changes of potential of the photo-elements are transferred through the miniature capacities to the metal plate, and from here the potential changes are amplified and applied to the radio transmitter.

The receiving apparatus consists of a more or less orthodox radio receiver coupled to a cathode-ray tube, known as a "kinescope" which differs from an ordinary cathode-ray oscillograph in several respects. At the large end of the cone-shaped tube is a fluorescent screen upon which the sharply focussed cathode-ray impinges and forms a bright spot of light. The screen is very thin, and sufficient light is transmitted outside for useful illumination. The incoming television signals appear in the receiver as a voltage of varying amplitude. This voltage is applied to a control element in the electron gun which controls the intensity of the beam and

therefore the brightness of the spot. To attain this condition, careful design is necessary, in order to avoid disturbing the focus or the velocity of the beam. The scanning is performed in the same manner as in the transmitter, exactly in synchronism, by deflecting coils, so that the spot draws the whole moving picture. Synchronism is effected by strong impulse signals at the instants when the picture is not being transmitted. The decay curve of the fluorescent screen requires careful consideration. If the decay is too rapid, flicker is apparent, and if it is too slow, the moving portions of the picture "trail." Difficulties due to secondary emission in the cathode-ray tubes were at first encountered, but were successfully overcome.

It is felt that the development of this type of equipment opens up new prospects for high grade television transmission. The fact that the iconoscope in the transmitter is practically a self-contained unit with a sensitivity approximately equal to that of a photographic film operating at the speed of a motion-picture camera with the same optical system, suggests wide fields of application which would not be possible with other methods.

Miscellanea

H.M. the King has approved the awards by the President and Council of the Royal Society of Royal Medals to Prof. G. I. Taylor for his mathematical work in physics, geophysics and aerodynamics, and to Mr. P. P. Laidlaw for his work on diseases due to viruses, including that on the cause and prevention of distemper in dogs. The President and Council of the Royal Society have also made the following awards: Copley medal to Prof. T. Smith, of Princeton, for his work on the diseases of animals and man; Davy medal to Dr. W. H. Mills for his researches in organic chemistry; Hughes medal to Prof. E. V. Appleton for his work on the effect of the Heaviside layer upon the transmission of wireless signals.

The Nobel prize for medicine for the year 1933 has been awarded to Prof. T. H. Morgan, For. Mem. R.S., of the California Institute of Technology. Prof. Morgan was professor of experimental zoology at Columbia during the period 1904–28 and is famous for his work in genetics. The 1933 prize for physics has been divided between Prof. E. Schrödinger and Prof. P. A. M. Dirac. Prof. W. Heisenberg has been awarded the prize for 1932.

Prof. F. Paschen, Prof. A. Sommerfeld and Prof. R. W. Wood have been elected Honorary Fellows of the Physical Society.

The following distinguished chemists have been elected Honorary Fellows of the Chemical Society: Prof. Auguste Béhal, Prof. Edward C. Franklin, Sir Frederick Gowland Hopkins, Prof. Camille Matignon, Sir Prafulla Chandra Rây, Prof. F. A. H. Schreinemakers and Prof. Adolf Windaus.

We have noted with regret the announcement of the death of the following well-known men of science during the past quarter: Sir John Biles, professor of naval architecture in the University of Glasgow; Dr. H. Bos, of Wageningen, founder of the *Acta Phænologica*; Prof. L. C. A. Calmette, For.Mem.R.S., assistant director of the Pasteur Institute, Paris; Prof. W. G. Craib, regius professor of botany in the University of Aberdeen; the Rt. Hon. Viscount Grey of Fallodon, statesman and ornithologist; Sir Alexander C. Houston, director of water examinations, Metropolitan Water Board; Dr. H. Lapworth, engineer and geologist; Sir Philip Magnus, educationalist; Prof. J. F. Marr, sometime Woodwardian professor of geology in the University of Cambridge; Sir A. Mayo-Robson, emeritus professor of surgery in the University of Leeds; Major Robert Mitchell, director of education at the Polytechnic, Regent Street, 1873–1922; M. Paul Painlevé, statesman and mathematician; Prof. L. J. Rogers, formerly professor of mathematics in the University of Leeds; Prof. F. Starr, anthropologist, of Chicago; Mr. H. F. Tagg, Keeper of the Museum of the Royal Botanic Gardens, Edinburgh; Dr. V. H. Veley, chemist, of Oxford; Prof. R. Ramsay Wright, emeritus professor of biology in the University of Toronto.

The Ramsay Memorial Fellowship Trustees have awarded the following new Fellowships for the year 1933–4: Dr. A. G. Winn, a British Fellowship of £300, tenable for two years at University College, London; Dr. N. W. H. Addink, a Netherland Fellowship of £300, at the University of Cambridge; Dr. J. Smittenberg, a Netherland Fellowship of £300, at the University of Bristol. In addition five other Fellowships have been renewed for the same year.

In 1928, the Agricultural Education Association appointed a committee to study and correlate (if possible) the modern methods of pasture analysis which have been employed successfully in Great Britain and abroad. The committee was unable to establish a standard basal method of analysis, but it has performed a very useful

service by publishing the results of its work in the form of a supplement (of 27 pages) to *Agricultural Progress*, vol. X, 1933 (W. Heffer & Sons, Cambridge, 5*s*. net). In this supplement the technique and indications for using each of the eight methods of pasture analysis are described and a comprehensive review of the history and literature is given.

The latest of the series of handbooks on the *Mineral Industry of the British Empire and Foreign Countries*, published by the Imperial Institute, deals with *Gemstones* (H.M. Stationery Office, 2*s*. 6*d*., or by post, 2*s*. 8*d*.) and summarises the economic and statistical information available on the subject.

The British Empire occupies an important position as a producer of gemstones. About five-sixths of the world's annual output (by value) of diamond is produced in the Empire ; principally in South Africa, Gold Coast, British Guiana and South West Africa. Smaller Empire contributors include Tanganyika, Sierra Leone, India and Australia. The Empire is also well furnished with supplies of other important gemstones. Australia contributes opal ; India and Ceylon provide jade, sapphire, ruby, spinel, agate, garnet, tourmaline, chrysoberyl, zircon, quartz gemstones, moonstone and many other less well-known varieties ; South-West Africa possesses tourmaline and beryl, and the Union of South Africa has deposits of beryl and emerald.

The introductory section of the Imperial Institute's publication deals, in a general and popular style, with the physical characters upon which the beauty and ornamental value of the stones depend, and briefly mentions the methods used for identifying different species. It is interesting to note some of the names which have been given by the trade to certain of the less popular stones with a view to improving the demand. Thus we find " Spanish topaz " (yellow quartz), " Brazilian emerald " (green tourmaline)," Matura diamond " (zircon), " Siberian ruby " (red tourmaline) and many others.

A description of the numerous minerals used as gemstones and their mode of occurrence is followed by an account of the methods used for cutting and polishing the stones, and by some notes on artificial gemstones. Other important sections are those on marketing and prices ; gemstones of several qualities and weights.

The main part of the book, as is usual in this Imperial Institute series, deals with each producing country, describing the stones obtained, the location, type and extent of the deposits, and the method of working. Technical data for the expert, and interesting

information of a more popular nature for the ordinary reader are also included.

The Inflammation of Coal Dusts : The Effect of the Nature of Added Incombustible Dust, by T. N. Mason and R. V. Wheeler, which has just been published as Safety in Mines Research Board Paper No. 79 (H.M. Stationery Office, price 6*d*. net) opens with a summary of certain earlier experiments described in the Sixth Report (1914) by the Explosions in Mines Committee of the Home Office with respect to the ability of different incombustible dusts to suppress the inflammation of a cloud of coal dust. On the basis of these experiments it has hitherto been assumed that the nature of the incombustible dust was immaterial, and that given a sufficiently fine mixture, all incombustible dusts, if of the same degree of fineness, were equally effective ; but preliminary experiments at the Safety in Mines Research Board Research Station at Buxton indicated that certain dusts were more effective than others and systematic tests of different incombustible dusts, which are described in the present paper, were therefore undertaken.

Tests were made with seven different incombustible dusts to determine their relative efficacy in preventing the propagation of coal dust explosions. The tests were made with two coal dusts of differing volatile contents and it was found that the quantities of the different incombustible dusts required to suppress inflammation were in the same ratio for the two coals. With Silkstone coal dust, under the conditions of the test 67½ per cent. of incombustible shale dust was needed to suppress inflammation, using limestone dust 57½ per cent. has to be added, and with gypsum only 40 per cent. In order, however, to assess the value of the various dusts under working conditions in the mine it is necessary to consider the ease with which the dust can be dispersed as a cloud. In this respect gypsum would appear to lose its superiority, for it is more likely to cake than either limestone or shale dust.

The *Bell Laboratories Record* for October, 1933, contains a description of the mode of manufacture and the properties of the latest types of cæsium-oxygen-silver photo-electric cells. The base or core of the cathode of these cells is a sheet of pure silver in the form of a segment of a cylinder. This sheet is covered with a matrix of cæsium oxide, silver oxide and finely divided silver and the matrix is itself covered by an adsorbed layer of cæsium of atomic dimensions in equilibrium with a small amount of absorbed free cæsium in the matrix. The anode is a nickel rod lying along the axis of the

cathode and the tube is either evacuated or is filled with argon to a pressure of a few hundredths of a millimetre of mercury. The vacuum cell prepared in this way is more than fifty times as sensitive as the potassium hydride cathode cell previously used and its response extends over a range from *c.* 3,000Å to 12,000Å with a maximum at 8,500Å in the infra-red. These figures are very much affected by variations in the thickness of the outer layer of cæsium, a layer 0·3 atom thicker than the optimum reduces the total sensitivity to 60 per cent., an extra layer 4·5 atoms thick reduces it to 25 per cent. The presence of the argon increases the sensitivity three-fold when the anode potential is 90 volts. The fact that a manufacturing process has been devised capable of the precision necessary in the micro-chemical processes involved in the production of these cells is not their least remarkable feature.

An article on fuses in the September issue of the same *Record* contains a short description of a fuse, intended for the protection of thermocouple circuits, which will blow at 0·025 ampere. It consists of a fusible resistance wire about 0·0004 inch in diameter mounted in an evacuated glass bulb. It was found that to produce a uniform wire of such fineness by drawing through a diamond die was very difficult and a process was devised whereby a thicker wire was reduced to the desired diameter by electrolytic removal, the size being controlled by resistance measurements as the wire passed through the electrolyte.

The *Bureau of Standards Journal of Research* for August 1933 contains a paper by R. H. Heald on the "Aerodynamic Characteristics of Automobile Models." The most interesting results were those relating to the resistance (drag) coefficients of cars of various types. This coefficient is defined by the ratio R/AV^2 where R is the resistance in lb. wt., A the projected frontal area in square feet and V the air speed in miles per hour. Its value varied from 0·0019 for a "1922 touring car" with its hood up (*i.e.* a car of the heavy Austin 12 type) to 0·0005 for a completely streamlined sedan with its whole upper surface smoothed and its wheels covered by the body. For a modern saloon of, *e.g.* the Riley type, the figure would appear to be about 0·0014. The author of the paper considers that this latter figure might be halved but only by some radical changes in mechanical design.

The August issue of the *Journal* contains also the results of measurements of the thermal expansion of columbium made by P. Hidnert and H. S. Krider. The rod used in the experiments was 30 cm. long and of 4·6 mm. diameter, the metal had a density of

8·572 gm. cm.$^{-3}$ at 24° C. and as received was slightly strain hardened. It contained 0·93 per cent. tin, and 0·26 per cent. iron. Their final equation was $l_t = l_0[1 + (7{\cdot}06t + 0{\cdot}00144t^2)10^{-6}]$ for the range −135° C. + 305° C. so that the coefficient of expansion is about 10 per cent. greater than that of tantalum. The July number contains a paper by Roeser, Schofield and Moser descriptive of an international comparison of the temperature scale between 660° C. and 1,063° C. The scales used by the Bureau, the National Physical Laboratory and the Reichsanstall now agree to about 0·1° C. at 850° C. (Gold point 1,063° C., silver point 960·5° C., antimony point 630·50° C., zinc point 419·45° C.).

The Oxford University Press announces the publication of a new issue of the *New English Dictionary on Historical Principles* in 12 volumes and a Supplement volume at £21 net. The Supplement deals with accessions to the language which have taken place during the last fifty years, words mainly introduced as a consequence of the advancement of scientific knowledge and to new usages (and invention) from America. The new issue contains 16,400 medium quarto pages and 1,800,000 quotations.

ESSAY REVIEW

CAUSALITY OR CHAOS (Ltd.)? By G. BURNISTON BROWN, M.Sc., Ph D., University College, London. Being a review of **The New Background of Science**, by SIR JAMES JEANS [pp. viii + 303] (Cambridge University Press, 1933. 7*s*. 6*d*. net), **Atom and Cosmos**, by HANS REICHENBACH [pp. 300] (George Allen & Unwin, Ltd., 1932. 8*s*. 6*d*. net), and **Causality**, by LUDWIK SILBERSTEIN, Ph.D. [pp. viii + 159] (Macmillan & Co., 1933. 4*s*. 6*d*. net).

AT the conclusion of a course of lectures on the philosophy of physical science Bertrand Russell, on being asked why he had not dealt with the subject of probability, replied "I find the whole question of probability a very difficult one and so I avoid it whenever possible." It is on this ground, where angels evidently fear to tread, that some of the younger generation of mathematical physicists have rushed in, with the result that of late both physicist and the man in the street have been subject to a welter of highly obscure literature, the chief reward for the perusal of which is the assurance that we are now free to will what we please (as long as it isn't anything very much). At any rate, we have been persuaded that a big change has taken place in the philosophical background of science, although philosophers would probably say that the real change consists in physicists having been forced to consider philosophical questions which formerly they had disdained, and which are, in fact, not new problems at all.

Sir James Jeans leads up to the question of indeterminism by a masterly survey of the methods of science and of the relativity views of space and time. His presentation of the new views of matter and of the origin of wave mechanics is a really brilliant piece of exposition. In spite of this, however, when he comes to discuss probability and causality his arguments fail to carry conviction. After explaining the principle of uncertainty he concludes that "we must suppose that the wave picture provides a representation, not of objective nature, but only of our knowledge of nature" (p. 236). "Thus the waves represent subjective probabilities" (p. 238). This seems satisfactory until we are told further on that

light waves also consist of knowledge and that this helps us to see "why modern physics does not need the old material ether, millions of times more dense than lead, for light waves to travel through" (p. 243).

Perhaps the only thing that is clear in this statement is that Sir James Jeans is intent on maintaining the idealist position which he put forward in his *Mysterious Universe.* Nevertheless, he has to distinguish between objective and subjective waves. This is because the group of waves representing an isolated electron spread with time until "after a time which we may treat as infinite, they fill all space. And as the position from which an electron started an infinity of time ago can have no possible influence on the position it may occupy now, the present electron waves are entirely independent of our knowledge, and so form an objective system. . . . This final system of waves is of course wholly objective: it cannot represent subjective knowledge for the simple reason that we no longer have any." This process by which waves which are subjective become objective with time is a very difficult one to understand and it is no help to realise, further, that since these waves cannot be represented in space and time they "cannot be said to possess any physical reality" (p. 250). Thus we may have waves which are completely objective ("in the sense that we must imagine them existing whether we experiment to discover their existence or not") and yet not possessing physical reality. Such a view can only be taken, of course, by one who adopts the idealist position. We are left, therefore, to presume that the events of this world still consist of thoughts in the mind of the Great Architect, though whether indeterminism is due to a fundamental vagueness in Its mental processes, or is only an illusion, the author leaves an open question (p. 260).

Let us turn now to the account of modern physics presented by the professor of Natural Philosophy in the University of Berlin. His book is an amplification of a course of broadcast lectures which aimed at giving insight into the physicist's way of thinking, a general view of the results of his research, and further at showing how the physical theories have united in a picture of the world. Taking into account the fact that knowledge "of the kind taught in schools" is not presupposed, it is difficult to see how a better book than this could be written on such a difficult subject. Professor Reichenbach must be congratulated on having produced a book which, for profundity and clarity, bears comparison with Max Born's *Einstein's Theory of Relativity* (Methuen). It is divided into four parts under the headings, "Space and Time," "Light and Radiation," "Matter,"

and "Philosophical Consequences." It is under the last heading that causality is discussed.

Reichenbach believes indeterminism to be established, although he admits that "it cannot be said that, at one stroke, it solves all those riddles which the anti-causal conception of psychical and physiological happening has proposed; for men's ways of acting, which seem to have purpose and meaning, the government of action by the will, and the associated feeling of freedom—these are all questions which have by no means yet been answered by the reduction of world history to a game of chance. We believe, nevertheless, that the desired solution finds new possibilities in the framework of these ideas, and that, in the end, this solution will be discovered" (p. 279). He approaches the subject by accepting Laplace's classical formulation of determinism, which is as follows: [1]

"We ought, then, to regard the present state of the universe as the effect of its anterior state and as the cause of the one which is to follow. An intelligence which, at a given instant, should have a complete knowledge of all the forces by which nature is animated and the respective situation of the beings who compose it—an intelligence sufficiently vast to submit these data to analysis—would embrace in the same formula the movements of the greatest bodies of the universe and those of the lightest atom; for it, nothing would be uncertain and the future, as the past, would be present to its eyes. The human mind offers, in the perfection which it has been able to give to astronomy, a feeble idea of this intelligence. . . . All these efforts in the search for truth tend to bring it nearer and nearer to the vast intelligence which we have just imagined, but from which it will always remain infinitely removed."

This undoubtedly is at the back of the minds of most scientific men when they consider the question of causality. Laplace, in his treatise on the philosophy of the theory of probability, upheld the subjective theory, which is the one that has been in favour ever since, *viz.* that the use of the laws of probability is necessitated by our own ignorance. All uncertainty of prediction is due to the limitations of human knowledge. The supreme intelligence would be able to calculate beforehand the results of games of chance. Now philosophical critics of the subjective theory argue as follows: "It is, in fact, not at all clear why, for instance, each face of a die should be uppermost about a hundred times out of six hundred throws, if the equal probability of the face corresponds only to human ignorance; we cannot imagine that nature should pay such close attention to man's incapacity" (p. 274). Reichenbach

[1] *Essai Philosophique sur les Probabilités.*

holds this to be a conclusive argument against the subjective theory of probability. He therefore favours an objective theory according to which "the regularity of statistical processes, such as those of aggregates of molecules, means a fundamental trend in natural events, the understanding of whose laws is quite as much the task of natural science as is the understanding of causal laws" (p. 274).

But the argument against the subjective theory is a very curious one, and, many will say, far from conclusive. The equal probability of the faces does not correspond to human ignorance but to the assumption of "insufficient reason" upon which *a priori* probability theorems of this kind have to be based. And the assumption of insufficient reason may be based not on ignorance but on a mass of accumulated knowledge. Our knowledge of the mechanics of elastic collisions, of moments of inertia of symmetrical bodies, and of the human difficulty of repeating very fine movements exactly, all lead us to suppose that there is no reason why all faces of the die should not be equally probable in the long run. If the experiments do not agree with the calculations, then the determinist looks for a cause not allowed for in the initial physical assumptions. What the indeterminist looks for is not so clear. At any rate our calculations are not based on ignorance and so it does not seem conclusive, to say the least, that since experiment confirms them, therefore "nature herself does not know what is going to happen."

Perhaps a rather more subtle plea for indeterminism is one which is put by Reichenbach thus: "It is not at all true that we ever find strict laws in nature. For all that we observe, each time, is that a law has been approximately fulfilled; a hurled stone, a flowing electrical current, a deflected ray of light, when exactly measured, will never show the course prescribed by the mathematical formula, but there will always be little deviations, so-called errors of observation, which may be decreased by better experimental devices, but can never be fully eliminated. How far, however, such errors influence the result of advance calculation can never be told *with certainty*. It can only be said that the errors will *very probably* occasion but a slight disturbance—but that is already a statement containing the concept of probability. Thus the idea of probability unavoidably enters the formulation of all laws of nature, if these laws are to be stated with complete conceptual rigour" (p. 275).

This is a very plausible argument, but the determinist can answer by pointing out that since the discovery of the atomicity of radiation, he no longer regards causality as a characteristic of nature which can be demonstrated with complete *experimental*

rigour. This does not prevent his using the notion of causality in his description of nature, however, and he is encouraged in this just because the lack of certainty in prediction "may be decreased by better experimental devices." The more careful the search, the more the determinism that is found, and this is true in biology and psychology as well as in physics. Consequently he attributes the indeterminism to defects in the experimental devices rather than to nature itself. Thus he believes with Einstein and Planck that those few cases, such as radioactive disintegration where, at present, no precise causation can be discovered, will yield in time with the advance of our knowledge. The principle of causality is not an empirical proposition capable of ever-increasing verification, but *a form of the theoretical system* (Einstein [1]) and a heuristic principle (Planck [2]).

This brings us to Dr. Silberstein's little book on Causality, since this is written in defence of determinism looked upon as a maxim of the naturalist rather than as a law of nature. This entertaining and somewhat mathematical treatise is dedicated to Miss Norma Shearer, but we are not told what she got out of it. We know, of course, what Miss Tallulah Bankhead thought of Sir James Jeans' *Mysterious Universe* because the Cambridge University Press printed it in their advertisements. She thought it contained What Every Girl should Know. Elsewhere we were moved to congratulate Miss Bankhead on her philosophical acumen.[3] It is to be regretted, therefore, that we do not know what Miss Shearer thinks of causality. However, the humble scientist and philosopher must regard it as evidence that his work is at last receiving the recognition it deserves.

Silberstein starts off by quoting W. K. Clifford to the effect that "the word represented by cause has sixty-four meanings in Plato and forty-eight in Aristotle." This leads him to attempt a definition which shall accord with its meaning in scientific use. He does this by considering a pendulum, or rather, the system pendulum plus Earth. He points out that this is not really an isolated system, and depends on the motions of the heavenly bodies, and ultimately on the universe as a whole, and since these possibly never repeat their state exactly, it is impossible practically to show that equal causes produce equal effects. The system, pendulum plus Earth, is, however, very nearly isolated and we can obtain a mathematical formula not involving the time explicitly (*i.e.* a

[1] A. Einstein, quoted by Sir H. Samuel, *Philosophy and the Ordinary Man*, Kegan Paul, 1932.

[2] Max Planck, "The Concept of Causility," *Proc. Phys. Soc.* 44, 245, 1932.

[3] *Philosophy*, vol. VI, No. 22, p. 243 (1931).

differential equation) which binds all the states of the pendulum together into a *line of states*. Any one of these states can be considered to be the "cause" of any other which comes *after*, and the latter will be the "effect" of the former. Such a system as this Silberstein calls a *complete* system. He then considers examples of *incomplete* systems, such as the solar system before the discovery of Neptune and points out that the assumption of strict causality led to the close examination of the perturbations and so to the discovery of Neptune. Here, he says, we see the great heuristic value of the notion of causality, and although we cannot be sure that we shall always be able to amplify an incomplete into a complete system, nevertheless it will be fruitful to try to do so. This maxim of behaviour is, according to Silberstein, the principle of causality.

In discussing radioactivity, he says, "The attitude of bare probabilities and indeterminacy, a comfortably lazy one, can in the best of cases be considered as temporary and provisionary, as something equivalent, in fact, to a veiled confession of man's ignorance of a host of possible details. But a resolute denial or abrogation of the deterministic principle with regard to the 'spontaneous' breaking up of atoms would certainly be premature. The whole question of radioactive disintegration, in fact, is barely in its infancy" (p. 93).

Laziness, however, is hardly a characteristic of the advocates of indeterminacy. The reason for this attitude is more likely due to the fact that those who are most vociferous in their expositions of the ways of nature at the present time are mathematicians and not physicists. And mathematicians, by their very nature, are glad to avoid anything so crude as an experiment, and of course, if we can believe Bertrand Russell, are always happiest when they do not know what they are talking about, nor whether what they are saying is true. At any rate, it is clear that Silberstein is in agreement with Einstein and Planck in holding that causality, although not ultimately demonstrable, is, none the less, a principle of great heuristic value.

Sir Arthur Eddington, in a very powerful attack on determinism,[1] complains that he attended a symposium of the Aristotelian Society and Mind Association to see what could be said against the abandonment of causality. Indeterminists were strongly represented, but apparently there were no determinists, and none in the audience either, and yet, he says, he can hardly believe that they are extinct. "Waking is a rude process, and if I sometimes shout it is because

[1] Sir Arthur Eddington, Presidential Address to the Mathematical Association, *Math. Gazette*, 16, 66, 1932.

current literature resounds with the snores of those who are asleep." Possibly scientific men in general are loath to bestir themselves because they feel that the renouncers of determinism ought first to define exactly what they mean by indeterminism. Needless to say, they never explain what they mean by such statements as "chance rules in nature" or "nature is at the bottom chaotic." Of course, these statements are led up to by discussing the statistics of insurance companies and games of chance: but no one has ever supposed that the illnesses, motor accidents, fires, etc., dealt with by insurance companies have not quite definite and ultimately discoverable causes. Neither has there been, as Reichenbach admits, any "serious doubt that, for instance, the result of every throw of a die is absolutely fixed by its initial conditions, such as the original position of the die and the force used by the player" (p. 273). Consequently these illustrations, though intriguing, are irrelevant.

As indeterminists are so reluctant to define what they mean by chaos or disorder, it may be instructive to try to define it for them. This is extremely difficult, especially for beings, the usefulness of whose ready-made reflexes and instincts is strong evidence for the uniformity of nature (even in mental reactions, which, it has been suggested, involve possibly only a few atoms). However, suppose we try:

"Chaos is a state of affairs in which anything can happen *and does.*"

But this won't do; it is much too thorough-going; it won't suit the indeterminists at all. Let us water it down then, for they want something much milder; like this:

"Chaos is a state of affairs in which anything can happen *but doesn't.*"

In spite of all the talk, for instance, about the possibility of kettles getting colder when put on the fire, in fact they never do and never will. It is just the last two words in this definition which show how complex their view of nature is. Complete chaos is a sufficiently difficult notion, but chaos that goes so far, and then is limited in some way, is even more difficult to comprehend.

The indeterminist view of Natural Law resembles the bar-parlour of a public-house, in which a certain amount of disorder is permissible, but as soon as it exceeds a specified limit, the Law steps in, and bodies with an excess of *vis viva* are subdued. Thus a macroscopic respectability is maintained, although the attribution of respectability to the ultimate constituents is both erroneous and

unnecessary. Perhaps this is sufficient to show what a complicated notion this one of chaos-up-to-a-point is, and helps us to see why Einstein rejects it as unsatisfactory and prefers the causal principle in view of its greater simplicity.

In conclusion, therefore, we may suppose that the determinists, rudely awakened by the declamations of the Renouncers of Causality, would reply somewhat as follows: we grant that experiment will never allow us to choose between strict causality and indeterminism in microscopic events; whether, therefore, we use the one or the other in the picture which we draw of nature will depend on three things (1) its power of linking together into a coherent and logical whole, as many of the known facts of physics as possible, (2) its heuristic value as a stimulus to further fruitful physical research, (3) its simplicity. As regards the first criterion, the new quantum theory might be said to have an advantage, but as Silberstein says, "its structure and technicalities of method are on the whole clumsy and, out of every proportion to the results actually yielded, ponderous and cumbersome, while its subsidiary assumptions, rules of the game as it were, far from being fixed, are being changed almost daily." So determinists are not willing to deny causality on this account. On criteria (2) and (3) determinism wins easily. Furthermore, there is evidence of determinism in macroscopic events, which increases with the accuracy of observation, while there is no experimental evidence for indeterminism of any kind. And finally, as the determinists prepare to renew their snores, they might suggest that if the indeterminists had paused to define what is meant by chance, by chaos, and by indeterminism, they would possibly never have been disturbed at all.

REVIEWS

MATHEMATICS

Foundations of the Theory of Algebraic Numbers. Volume II: The General Theory. By HARRIS HANCOCK, Ph.D. [Pp. xxvi + 648.] (New York: The Macmillan Company, 1932. $8.00.)

THIS book provides a mine of information on the whole of the older theory of algebraic numbers. The Dedekind moduls and ideals and the Kronecker forms are discussed fully, the two theories being put in juxtaposition. Two expositions of algebraic units are given, the one from the standpoint of Dirichlet and Dedekind, the other from that of Minkowski and Hilbert. One chapter consists of extracts from Minkowski's Geometry of Numbers. The theory of ideal classes is also treated. Later in the book come three chapters on the Galois theory in Galois fields of rationality.

The book obviously represents a vast amount of work on the part of the author, who must have used most of the original memoirs of the mathematicians mentioned above and, among others, of Hurwitz and Hensel. The methods and theory appear, however, somewhat old-fashioned; the author makes almost no use of modern algebraic methods, so that the path of the student of the theory is made longer and more troublesome than is now necessary. On the other hand, the actual details are clearly explained, and, if we must travel this way, Prof. Hancock will make the path remarkably smooth.

E. M. W.

The Fourier Integral and Certain of its Applications. By NORBERT WIENER. [Pp. xi + 201.] (Cambridge University Press, 1933. 12*s*. 6*d*. net)

THIS valuable book is written by one of the leaders of research in the important field which it covers. It is based on a course of lectures delivered at Cambridge in the spring of 1932. The introduction contains a short account of the properties of the Lebesgue integral, of the Riesz-Fischer theorem and of parts of the theory of orthogonal functions. Then follows the formal theory of the Fourier transform, Plancherel's theorem of the existence of the transform of a function of class L_2, and the associated Parseval theorem. The next group of ideas dealt with is that involved in general Tauberian theorems. We have also applications to the problem of the distribution of the prime numbers. The book closes with the theory of the spectrum of a function and the Weierstrass and Parseval theorems for almost periodic functions.

For a systematic treatment of the Lebesgue integral the reader is referred to the standard books on the subject But a résumé of the chief theorems are given in the introduction It is somewhat amusing to read that " none

but the extremely indolent will content himself with taking the proof of these fundamental theorems on faith." The author need feel no anxiety; "extremely indolent" people are unlikely to read his book.

The bibliography only includes papers cited in the text. A complete bibliography would be useful, but for this we are referred to two papers of the author.

E. M. W.

Principles of Descriptive Geometry. By E. L. Ince, M.A., D.Sc. [Pp. viii + 152, with 153 figures.] (London: Edward Arnold & Co., 1933. 8s. 6d. net.)

The study of Descriptive Geometry has in this country been confined almost exclusively to those whose occupations or professions necessitate the construction and use of diagrams representing solid objects to scale. As a subject of general education or more particularly as part of a scientific curriculum, it has generally been neglected, although it affords a most valuable aid to the understanding of spatial relations. The ideas which underlie it are of a simple character, in fact involving nothing more than the elementary principles of geometry first formulated two thousand years ago.

One of Dr. Ince's aims in writing this book is to show the desirability of including a course of Descriptive Geometry in the general mathematical curriculum. In seven chapters he develops the theory of the subject and side by side shows its application to practical problems. The material is sufficient for a first-year course, proceeding as far as a discussion of the simpler polyhedra, but excluding the more difficult cases of curved surfaces which he hopes to treat later.

A merit of the book is that it is not overloaded with detail, and there is no danger of the student failing to keep in sight the great basic principles involved. In addition to exercises of the usual type requiring constructions to be made with given measurements, there is a large number illustrating cases of a general character and linking the subject up with the study of pure geometry.

J. B. D.

Elements of Co-ordinate Geometry. By J. M. Child. [Pp. xiv + 468.] (London: Macmillan & Co., 1933. 12s. 6d. net.)

Mr. Child has had much experience as a teacher of mathematics and this is reflected in the present book, in which the clearness of exposition is admirably adapted to the needs of the first and second year students at the Universities for which it is presumably intended. The book opens with a lengthy introduction of the idea of co-ordinates and the equation of the straight line. In particular, a definition is given of the "direction" of a straight line. Next comes an account of the standard properties of the conic sections, followed by a chapter on harmonic ranges and on poles and polars.

The problem of exposition afforded by the "line at infinity" is very difficult. It is here introduced before general homogeneous co-ordinates have been discussed. While the analytic treatment is good, the vaguer comments are not so satisfactory. The latter are, however, very few; one feels that they could have been omitted altogether. Surely every effort should be made at first to confine oneself to an analytic definition in terms of general homogeneous co-ordinates. The author rightly avoids the meaningless definition of the line at infinity as the line $n = 0$.

The treatment of general homogeneous co-ordinates is very satisfactory and thorough, and the book concludes with a series of notes on more advanced topics.

The object of the book is to emphasise the "co-ordinate" aspect of the subject rather than the "conics" point of view. While this is a step in the right direction, one could wish that the author had gone further. Homogeneous co-ordinates could be introduced sooner and much more made of line co-ordinates and the "principle of duality." The latter principle, one of the most interesting in geometry, could be introduced by an extended account of poles and polars. Probably the author would have been only too glad to have gone further in this direction, but was restrained by the laudable desire to make the book wholly comprehensible to the weaker brethren and by the necessity of writing a text-book suitable to the present state of examinations.

E. M. W.

ASTRONOMY

Planetary Co-ordinates for the Years 1800–1940. Prepared by H.M. Nautical Almanac Office. [Pp. xviii + 156.] (London: H.M. Stationery Office, 1933. 12*s*. 6*d*. net.)

For many years the Nautical Almanac maintained an almost static existence, but, since the advent of Dr. Comrie, it has shown numerous changes, enlargements and rearrangements. The issue of this volume of planetary co-ordinates marks, however, a still greater break with tradition, for it is designed for the help of astronomers engaged, not in actual observation, but in the calculation of the perturbations of comets and minor planets and in the preparation of accurate ephemerides.

The tables are planned for use in connection with the rectangular co-ordinate methods of Encke and Cowell, and will relieve the work of the dynamical astronomer of a great part of its drudgery. All data are referred to the equinox of 1950·0, a standard which should serve for another fifty years. For each planet are given the heliocentric longitude and latitude, the radius vector and its logarithm, $1 - r^3$, the equatorial rectangular co-ordinates, and the attractions on the sun. Auxiliary tables are also provided, with the result that all the requirements for a computation of special perturbations by Cowell's method are satisfied in this one volume, while those who prefer Encke's method need only supply themselves with a table of sines. The table of collected formulæ, the concise explanation, and the working out of illustrative examples will all be greatly to the convenience of the computer. The arrangement is in a form suitable for use with calculating machines.

Dr. Comrie is to be congratulated on his success in persuading the Admiralty to publish this valuable work, especially in these times of financial stress.

R. W. W.

The Herschel Chronicle: The Life-Story of William Herschel and his Sister Caroline Herschel. Edited by his Granddaughter, Constance A. Lubbock. [Pp. xii + 388, with 9 plates.] (Cambridge: At the University Press, 1933. 21*s*. net.)

This book is a most interesting and authoritative contribution to the Herschel literature. It is largely composed of carefully chosen selections from the correspondence of William and Caroline Herschel with each other and with

their relatives and scientific friends. These letters are supplemented by numerous extracts from Caroline's Journals, and other memoranda, which throw many sidelights on the domestic life of the brother and sister during most of their fifty years of collaboration. Around these extracts is woven a continuous narrative which begins with all that can be gleaned about the progenitors of the Herschel family, follows William and Caroline Herschel through their long and laborious careers, and, before breaking off, shows John Herschel applying his father's methods to the survey of the southern heavens. The three brothers, Jacob, Alexander and Dietrich Herschel, to whom William and his sister showed much kindness (not always requited), have also their due place in the story. The wealth of detail here presented with such loving care could only have come from the pen of one saturated in the family traditions, who yet never allows her own shadow to fall on the pages.

The authoress does not profess to give a technical account of the astronomical labours of the Herschels such as has already been supplied by Dreyer and other authorities. But the general reader will find a sufficient indication of their principal achievements, illustrated by extracts from Herschel's contributions to the Royal Society. A list of these contributions is given at the end, and other appendices include extracts from Fourier's *éloge* of Herschel, and English translations of the epitaphs of the astronomer and his sister. A genealogy of the principal figures in the Chronicle might have been helpful to the reader.

The volume is beautifully printed and well bound. The plates include three portraits of William Herschel, and one of Caroline, besides illustrations of the principal instruments which they employed. Of especial interest is a photograph, expressly taken at the Lick Observatory for inclusion here, of the nebulous star (N.G.C. 1514) whose discovery first suggested to Herschel that at least some nebulæ might be composed, not of remote stars, but of "a shining fluid of a nature totally unknown to us."

A. A.

Makers of Astronomy. By Hector Macpherson, M.A., Ph.D., F.R.S.E., F.R.A.S. [Pp. viii + 244, with 9 plates.] (Oxford: At the Clarendon Press, 1933. 7*s.* 6*d.* net.)

This book, which is based on recent lectures delivered by the author at Glasgow, consists of biographical sketches of about 60 astronomers ranging from Copernicus to men still active to-day. The contributions of each to astronomy are briefly indicated, with illustrative quotations, only common knowledge of the subject being assumed.

The subject-matter of the book has been admirably selected and digested. Though the earlier pages naturally contain much that has frequently been told already, the interest steadily increases in the later chapters. These afford much information about recent work not yet generally accessible in standard histories, much of it by men personally known to the author. A few introductory pages might perhaps have been included on the development of astronomy before Copernicus. Scarcely even incidental reference is made to earlier workers, and in consequence the book seems to start a little abruptly. Again a page might well have been devoted to John Goodricke for his pioneer work on variable stars.

Dr. Macpherson's volume, however, will prove of interest to all students

of the modern history of astronomy, as well as to general readers. It is well printed on stout paper, and will take a worthy place among its companions in the "Makers of Science" series. The plates show representative astronomers and celestial objects, and there is a full index. We have noticed the following misprints: in the Latin on p. 104 (l. 16) *peruppit* should be *perrupit*; on p. 133 (l. 8) *precision* should be *precession*; and on p. 229 (l. 16) *60,000* should, judging from the context, be *80,000*.

A. A.

PHYSICS

The General Properties of Matter. By F. H. NEWMAN, D.Sc., and V. H. L. SEARLE, M.Sc. Second edition, revised. [Pp. 388, with 113 figures.] (London: Ernest Benn, 1933. 18*s*. net.)

THIS is the only book in English giving a comprehensive account of its subject at the standard required by students reading for an Honours degree in Physics, and it is, therefore, not surprising that a second edition has been called for five years after the appearance of the first. One excellent feature of that edition was its up-to-dateness; it appeared in 1928 and there were a number of references to papers published in 1926. No attempt has been made in the new edition to retain this very desirable feature; one reference only appears to have been added, namely to a letter on the temperature variation of viscosity written by Prof. Andrade to *Nature* in 1930. One looks in vain for the name Lennard-Jones in the index; even Heyl's redetermination of the gravitational constant at the Bureau of Standards in 1930 is ignored. There can be little doubt that the omission of references to important work carried out in the period 1927–31 is due to a desire to disturb the set up of the book as little as possible, and this in itself is unfortunate, for an entire resetting would have added much to the appearance of the print and the comfort of the reader. When all is said and done, however, these grumbles merely amount to a desire for more of a good thing. The book remains indispensable and in its new edition is at least, it is hoped, "free from any errors of importance."

D. O. W.

Statistische Mechanik auf quantentheoretischer Grundlage. By PASCUAL JORDAN. [Pp. x + 110.] (Braunschweig: Friedr. Vieweg & Sohn, A.G., 1933. R.M. 8.20 Bound, R.M. 6.80 Paper Covers.)

WHILE there are many small books of an introductory character on the recent developments of the Quantum Theory available for readers, who wish to begin the subject, short works on the newer developments in statistical theory are rare. The developments of the Quantum Theory have altered this theory profoundly and it is high time that the changes should be known to physicists and taught to students. Prof. Jordan has rendered a service in undertaking what is almost a pioneer work by writing a short account of this branch of modern physics.

There are several ways of introducing modern statistical theory, but he has chosen one which will appeal to those who are familiar with the theory of Maxwell, Gibbs and Boltzmann. He holds that a clear insight into the problem will be best obtained by following the path of these investigators. He thus devotes the first chapter to the classical statistics of the ideal gas, introducing the reader to Maxwell's partition and Boltzmann's H-theorem.

This is a short chapter of only twelve pages and from this point the Quantum Theory is the basis of the discussion, the older theorems appearing in quantum form. The author is continually carrying out his plan of translating as faithfully as possible the procedure of the classical writers into modern language.

Although it is possible to maintain, as some other writers do, that the older views can be completely dispensed with, it is probable that those physicists who are witnesses of the change which is taking place, will find Jordan's procedure more in accordance with their taste. The teacher will have to decide whether he will follow the historical development or whether he will turn his back upon everything that happened before the revolution.

The keen student will learn much from, or in spite of, either method. One advantage of the method described is that a reader acquainted with the classical theories and with the simple conceptions of the Quantum Theory, such as discrete states, probabilities of transition and uncertainty rules, can proceed easily along the course followed. The book is of necessity largely concerned with the more formal side of the subject and it is difficult in a short space to come to the practical applications. The treatment of the degenerate gas is given but there is no attempt to include a study of the theory of electrons in metals. This is much to be regretted on account of the importance and interest of the subject and also on account of the desire of a large number of physicists to acquire some knowledge of the developments in this connection. The author's original plan to include a discussion on this subject was not carried out, though it would have been much easier for the reader to have continued with the notation and method of the book rather than to turn to the works quoted.

In its form the book consists of rather short paragraphs into which the subject is somewhat condensed. There is much mathematical formulation and not very much general discussion, so that reading is somewhat slow, but the details of the subject are set out very clearly and the book has a quality which all small books should possess; it will drive the interested reader to larger works.

H. T. F.

The Measurement of Air Flow. By E. OWER. Second edition. [Pp. viii + 243, with 85 figures.] (London: Chapman & Hall, Ltd., 1933. 15*s*. net.)

THIS book, which first appeared in 1927, although quite specialised in scope, has proved its usefulness to engineers whose work involves the use of anemometers, by requiring a new edition in the short space of five years. Additions have been made to keep in line with recent research and the design of new instruments, notably in the chapters dealing with the orifice flow meter, pitot-tube and vane anemometer. A large proportion of the theoretical treatment is based on the author's own work at the National Physical Laboratory. The author admits that theory took up too large a proportion of the original edition, and has therefore added a new chapter containing examples of the application of the formulæ in the practice of ventilation and gas engineering.

The book might have been improved if more copious references had been given. There is only one bibliography (on hot-wire anemometry) and that is not complete. The use of this instrument for measuring fluctuating flow, as

developed in a number of laboratories at home and abroad, is not discussed. Nevertheless, we feel sure that the book will provide stimulating reading, not merely for those for whom it is primarily intended, but for all those interested in aerodynamics. It is ably produced and copiously provided with graphs and tables.

E. G. R.

An Outline of Atomic Physics. By Members of the Physics Staff of the University of Pittsburgh. [Pp. vii + 348, with 160 illustrations.] (New York: John Wiley & Sons, Inc.; London: Chapman & Hall, Ltd., 1933. 21*s.* 6*d.* net.)

This outline of modern physics is a very pleasing example of what may be accomplished by the active co-operation of the members of the staff of a large physics department. The seven contributors to this volume have set themselves the task of providing an account of the developments of modern physics and modern astrophysics which may be read with appreciation by those whose knowledge of physics is quite elementary.

In this task they have achieved a considerable amount of success. Their book is well illustrated and contains a minimum of mathematics. It is up-to-date, for it contains sections on the neutron and on the isotope of hydrogen of mass 2. It is easy to read, and their account of the development of the wave and corpuscular theories of light and of matter is particularly to be commended.

The book will not be of signal service to students who intend to specialise in physics, but it should be of considerable help and interest to those who do not intend to pursue recognised courses in physics beyond the intermediate stage, and to those who need a simple introduction to the complexities of modern physics.

L. F. B.

Radioactivity and Radioactive Substances. By J. Chadwick, M.Sc., Ph.D. Third edition. Pitman's Technical Primers. [Pp. xii + 116, with 33 figures.] (London: Sir Isaac Pitman & Sons, Ltd., 1932. 2*s.* 6*d.* net.)

This little book well deserved to reach its third edition, for it provides a very charming elementary introduction to the facts and problems of radioactivity, and it is unnecessary further to praise it here. The reviewer would however suggest that the curve on page 18 be amended, and he regrets that no mention of the neutron is made by its discoverer; perhaps this edition should more fittingly be termed a reprint.

L. F. B.

Thermionic Vacuum Tubes and their Applications. By E. V. Appleton, M.A., D.Sc., F.R.S. [Pp. vii + 117, with 68 diagrams.] (London: Methuen & Co. Ltd., 1932. 3*s.* net.)

In this contribution to Messrs. Methuen's series of Monographs on Physical Subjects, Prof. Appleton deals with the construction and internal action of thermionic valves and with their many and various applications as amplifiers, rectifiers, and oscillators. In his own words, the author has "tried to include matter which would most likely be of interest and use to a student of general physics who has not made a special study of radio-frequency

phenomena." This intention is admirably fulfilled and a remarkable amount of information has been compressed into the space available. The treatment of the input impedance of a triode in Chapter VI is likely to be a little bewildering to those new to the subject, and the reader should be warned that the values of the inter-electrode capacities appropriate here are not the same as those intended in Chapters V and IX although designated by the same symbols. Many useful references are included, and the book can be thoroughly recommended to those looking for an introduction to this important subject.

N. L. Y.-F.

Wireless Receivers: The Principles of their Design. By C. W. Oatley, M.A., M.Sc. [Pp. vii + 103, with 41 diagrams.] (London: Methuen & Co., Ltd., 1932. 2*s*. 6*d*. net.)

Another of Messrs. Methuen's Monographs on Physical Subjects. After some introductory remarks on modulation and distortion, the author deals briefly with the equivalent circuit of a triode and the input impedance effect. We are then taken through the receiver stage by stage from aerial to power valve, the function and mode of operation of each stage being clearly explained and subjected to simple mathematical analysis, special attention being paid to the conditions necessary for the avoidance of distortion. Some omissions had to be made, and the superheterodyne type of receiver is not dealt with. The author has aimed at the exposition of general principles rather than practical details, and the reader must turn to the current technical press for information on the various devices which must be employed in the application of these principles to the practical problem of design.

N. L. Y.-F.

Alternating Current Electrical Engineering. By Philip Kemp. Fourth edition. [Pp. xi + 595, with 418 figures.] (London: Macmillan & Co., 1933. 15*s*. net.)

The volume under review is the fourth edition of a book which was first published in 1918. Since that time the work has been considerably expanded and improved. In the present form it should satisfactorily meet the needs of any student of the subject who wants a thoroughly sound and clear exposition of essential features without going into a more detailed analysis of the problems involved than is necessary for that purpose.

One of the principal difficulties in the preparation of a book of this kind is to decide what should be omitted from its pages. The title covers a field so extensive that a single volume could scarcely be expected to do justice to the whole of that field from all aspects, and whatever scheme is adopted to bring the treatment within the desired compass there will always be differences of opinion regarding its merits.

The author explains that he has set out "to adhere to principles rather than to go into details of particular types of machinery and apparatus"—a most praiseworthy object and one to be highly commended, particularly in these times when the general tendency seems to be towards premature specialisation. In his general plan the author has undoubtedly succeeded admirably but one cannot help feeling that in certain sections he has departed to some extent from his avowed intention.

Thus the design calculations for particular types of transformer, induction

motor and alternator might well be omitted. The student who wants to study such calculations will naturally go to the specialist book on design of electrical machinery for them.

The space given up to these calculations might be very profitably employed by making the treatment of the oscillatory circuit, alternating current networks and measurements rather more comprehensive.

In developing his subject the author adheres to what has become more or less accepted practice. Starting with the fundamental principles governing electro-magnetic induction, he proceeds to investigate the particular case of an alternating E.M.F. and to show how different types of electric circuit, including resistance, inductance and capacitance respond to its action.

Vector diagrams are introduced freely to assist in the explanation of the various problems and the effect of higher harmonics in the wave form is briefly considered.

Polyphase currents are then dealt with and the manner in which they can be employed to produce a rotating magnetic field is explained.

Up to this point the treatment forms what may be considered to be an introduction to that which follows, including A.C. measuring instruments, transformers, alternators, the principal types of A.C. motor, rotary converters, motor converters, frequency changers, rectifiers, methods of power factor control and protection of A.C. systems. There are also short chapters devoted to the symbolic notation of vector algebra, transients and the oscillatory circuit. The introduction of the symbolic method of analysis at this late stage is difficult to understand. The method might with advantage have been used throughout the book to supplement if not to replace the usual treatment, which is often somewhat laborious.

A number of useful numerical questions are given at the end of each chapter and the solutions appended. The author has kept his eye on recent developments and these are mentioned wherever possible together with reference to some novel devices not generally found in a book of this kind.

H. M. Barlow.

CHEMISTRY

Report on Band Spectra of Diatomic Molecules. By W. Jevons, D.Sc. [Pp. 308, with 4 plates and 65 text-figures.] (London: The Physical Society, 1933. Printed by the Cambridge University Press. 17*s.* 6*d.* paper, 20*s.* 6*d.* cloth.)

This admirable report will serve two purposes, it will help to enable physicists and physical chemists with no experience of the interpretation of spectra to undertake such a task with far less trouble and a greatly simplified course of specialised study than previously, and it also provides an excellent reference book to most of the spectra of diatomic molecules that have so far been analysed.

On the whole the work can best be described as a highly specialised text-book of this very important branch of physics, and in which special attention has been given by the author to some of the subjects such as Raman spectra and Heats of Dissociation that are of special interest to the physical chemist. The author was certainly wise to exclude the discussion of valency on the grounds of its remoteness from the main theme. It differs from a text-book in that it contains detailed accounts of all the important band systems of diatomic molecules which had been described up to October 1932.

There are many good features of the book which should be noted. There is an admirable index, an appendix on notation in the form of a glossary which is particularly necessary in a subject such as this in which the notation is one of the main sources of difficulty, and there are very many diagrams which seem much clearer than most diagrams of energy levels.

The book was printed by the University Press at Cambridge, whose standard is well known. It might be used as an example of how to make an attractive-looking page from the most unpromising material.

A great debt of gratitude is due to the Physical Society for sponsoring this work, and to the author for undertaking the great labour it must have entailed.

O. H. W. J.

The Colloid Aspects of Textile Materials and Related Topics. [Pp. 368, with numerous plates and figures.] (London: The Faraday Society, 1933. 15*s*. 6*d*. net)

The general lines of the Faraday Society discussions are now so well known that reviews of them need only describe the contents of the particular volume. This one covers an even larger field than its name implies, and will be of the greatest value to anyone who is interested in colloids generally—not only in textiles.

The first section on "Raw Materials and their Constitution" contains important papers by Mark, Staudinger, Adam, Trillat, and Jordan Lloyd, to mention only a few. Part II, which refers particularly to fibre particles, is particularly interesting as an example of the work now being done on the border line subjects lying between purely academic and purely industrial research, some contributions from the British Silk Research Association's Laboratories being particularly noteworthy in this respect. Part III, on "Manufacturing Processes," contains amongst others two interesting papers on the theory of dyeing, by Profs. Elod and Ostwald.

It will be remembered by many that this was a very well attended meeting, so that the discussions reported at the end of each paper are of great merit. It is nearly certain that every worker interested in colloids, and particularly in proteins or textiles will have to obtain this collection of papers if, which is unlikely, he does not already possess it.

O. H. W.-J.

Gas Analysis by Measurement of Thermal Conductivity. By H. A. Daynes. [Pp. viii + 357, with 76 text figures.] Cambridge: The University Press, 1933. 16*s*. net.)

This book deals with the experimental technique of the method, first developed by Schleiermacher, of measuring the thermal conductivity of a gas in terms of the power supplied to an electrically heated wire immersed in a cell containing the gas. The original investigator employed the method to determine the conductivities of gases at low pressure. The procedure is now reversed; the problem is to determine the composition of the gas from the known conductivities of likely constituents, usually in terms of a standard such as air. The development of this method in its military applications is a striking example of independent work by scientists on the various fronts during the European War leading to virtually the same solution. The problem was

originally that of the detection of leakage of gas from airship envelopes. Hydrogen, along with carbon dioxide and sulphur dioxide, having a thermal conductivity very different from oxygen and nitrogen, lends itself extremely well to detection by this method; and so there were evolved the Shakspear "katharometer" in this country, the Siemens-Halske meter in Germany, and the flow-meter adopted by the American Bureau of Standards. In the improvement and further industrial application of the first of these instruments, Dr. Daynes has taken a main share, and all whose work brings them in contact with gas analysis will be indebted to him for writing this book. Even those who are not directly interested in this sphere of technology will find much of interest. The chapter on the various types of Wheatstone Bridge will be of use to all concerned with the measurement of small changes of resistance, while not the least interesting chapter is that dealing with the various technical and research problems to which the katharometer has been adapted. There is only one criticism to be made. It is stated that "the method is sometimes more and sometimes less convenient than the older methods." A critical comparison of the new and the old methods, with some description of the latter, would, one feels, have enhanced the value of the book.

E. G. R.

The Conductivity of Solutions. By C. W. Davies, D.Sc. Second edition: revised and enlarged [Pp. x + 281, with 32 figures.] (London: Chapman & Hall, Ltd., 1933. 15s. net.)

Recent developments of the theory of electrolytic dissociation have led to a great revival of interest in the electrical conductivity of solutions. It is not surprising, therefore, that a book dealing specifically with this subject by an author who has himself made notable contributions to its theoretical and practical development should have reached a second edition within a period of four years. Apart from the considerable expansion of the sections on conductivity titrations and other applications, and the allocation of these sections to a separate part of the book, the general arrangement of the text is substantially unaltered; but almost every section has been modified or expanded in the light of more recent work. In particular, new information has been added with regard to methods of measurement, dissociation of weak ternary electrolytes in water, deviations from Ohm's law, the solvent correction for a hydrolysed salt, complex formation in bi-bivalent salt solutions; and all the tables of data have been revised. Due attention has been given to the extensive work carried out in recent years on the conductivity of non-aqueous solutions, and the book contains a valuable summary of experimental results and theoretical conclusions in this important field.

The present reviewer would like to have seen some re-arrangement of the subject matter in this new edition. Thus, the various facts and concepts which are the essential ingredients of the general theory of electrolytic dissociation now emerging are still rather widely scattered (Chapter II, V, XI and XVIII), so that it is not very easy to assess their relative significance in the general scheme. This is the more remarkable because the author himself has been especially concerned with the welding together of these various ideas into a consistent general theory. On the other hand, the arrangement adopted helps to direct attention to the practical side of the subject and to maintain a close relation between certain aspects of the theory

and the relevant experimental results. In so far as it does this, it is not without merit.

Very complete references to original work are given; the tables of data are thoroughly up-to-date; and the diagrams are clear. The printing and the general get-up of the book are very good.

H. J. T. E.

Physical Chemistry. An Introduction to first Principles. By A. K. Goard, Ph.D. [Pp. vii + 222, with 25 text figures]. (London: Sidgwick & Jackson, Ltd., 1933. 5*s*.)

There is now such a great number of elementary text-books in all branches of chemistry that it is rare to find a new book definitely filling a gap. It is the reviewer's belief that Dr. Goard's elementary introduction to General and Physical Chemistry is one of the few that does so, and since it does so very well indeed, it ought to prove very popular.

It is intended as a first introduction to the study of physical chemistry, taking the pupil up to the standard of most elementary qualifying examinations in Chemistry. Since it makes no claims to go beyond this stage, where several excellent text-books are already available, no charge of omission should be made against it. Those subjects which it treats are frequently just those which are apt to be included in an abbreviated form in Inorganic text-books, in which form their real significance is often overlooked with the result that the basic principles of general chemistry are not really grasped by the student when he is taught to use the methods. It seems to have been the intention of the author to give an account, mainly qualitative, of elementary physical chemistry which can really be easily understood by the beginner, and his aim is obviously a highly desirable one.

He has moreover succeeded in doing so. In the nature of things, some of the explanations of the phenomena discussed seem rather lengthy to anyone accustomed to the more advanced type of physico-chemical text-book, and the style is more informal than is conventional, to the great advantage of the book. A detailed study of the book failed to reveal the common fault of elementary books of making things seem easier than they are, by the process of leaving out the difficulties, or of giving explanations of limited truth; but the author's gentle introduction of some of his views on the elementary philosophy of science in the two earlier chapters left the reviewer with little expectation of detecting such faults. This seems to be one of the few elementary text-books of importance.

O. H. W.-J.

The Methods of Cellulose Chemistry. By Charles Dorée, M.A., D.Sc., F.I.C. [Pp. x + 499, with 67 figures.] (London: Chapman & Hall, 1933. 21*s*. net.)

Cellulose, in one form or another, may be said to be almost as widely distributed in industry as in nature, so numberless are the fascinating and useful products that may be obtained from it and its derivatives. Few other substances are so stable, and yet at the same time potentially so mutable. An immense volume of research work has accumulated on every aspect. But since with almost the sole exception of the cotton boll, cellulose is not found unassociated with other plant constituents, the first step is its isolation. The methods adopted vary profoundly with the source and its

intended fate, and the "cellulose" of one industry may be useless in another. Indeed, the definition of quality depends solely on the use which is subsequently to be made of it. It is this fact which has so complicated the whole field of cellulose chemistry. And further, circumstances seem to have made of investigators specialists in one field so that the subject, since the hey-dey of those sturdy pioneers, C. F. Cross and E. J. Bevan, has lacked men of broad vision and interpretative ability. For these reasons, it would be difficult to overrate the value of the service done to his subject by Dr. Dorée in compiling and selecting this wholly admirable review of methods used in all branches of cellulose chemistry. Sufficient details are given of the various methods mentioned, and typical results quoted, so that reference to the original is not essential, save for research purposes.

The book is divided into three sections; the first dealing with "normal" cellulose, by which appears to be implied cotton cellulose, the second, cellulose esters, and the third, the so-called "compound celluloses." All are well and capably covered. The first section will appeal most to those with applied and textile interests, and the third to plant chemists and those with a more academic outlook. Though the author briefly rejects the wholly unjustifiable classification of "compound celluloses," it is perhaps unfortunate that he gives it his tacit support by the use of the term and the arrangement he adopts. This third section is distinctly a mixed bag, always interesting, but sometimes not precisely in keeping with the aims of the book as very definitely defined in the Preface. It ranges from the investigation of pulps to the chemistry of isolated lignin (with too little of the former and too much of the latter), from an excellent chapter on the estimation of furfural to a lengthy and amorphous one on hemicelluloses. Minor criticisms may be made, *e.g.* that rather too great a prominence is given to the methods of analysis of wood proposed by W. H. Doro, to the exclusion of those more widely employed, and more widely applicable, or that no mention is made of the promising Ross-Hill method for the estimation of lignin. But such points are mere quibbling and expressions of personal idiosyncrasies. One verdict alone is possible—excellent.

GEOFFREY NORMAN.

Organic Chemistry. By F. SHERWOOD TAYLOR, Ph.D., M.A., B.Sc. [Pp. xii + 587, with 56 figures.] (London: William Heinemann, Ltd., 1933. 10*s.* 6*d.*)

A Short Organic Chemistry. By F. SHERWOOD TAYLOR. [Pp. viii + 378, with 43 figures.] (London: William Heinemann, Ltd., 1933. 5*s.*)

MANY might think that it would be difficult to justify yet another text-book of elementary organic chemistry, but the first of the above volumes contains elements of novelty which make it welcome. In Chapter II the distinction between polar, covalent and co-ordinate linkages is pointed out and, although some might not entirely agree with the author's exposition and insufficient emphasis is laid on the bearing of these types of valency on organic and inorganic chemistry, the introduction of these ideas into text-books of organic chemistry is long overdue. The quinquevalent nitrogen atom is not employed, but cacodylic acid is written with a quinquevalent arsenic, and although the electron theory is invoked from time to time, it is not overdone. The treatment of optical activity is much more modern than is generally the

case in such books, but it is not made clear that the asymmetry of a molecule containing four different groups attached to a carbon atom is only a special case, whilst the meso form is still regarded as due to the neutralisation of two opposite rotations instead of disappearance of molecular asymmetry. The sugars are dealt with in some detail and the ring structures employed, a very desirable introduction if the existence of the α- and β-sugars is to be explained.

A good deal of emphasis is placed on compounds of biological importance, and the author states that the needs of the medical student have been given first place in selecting the matter to be treated, but the reviewer is of opinion that the book is really more suited for the student of pure chemistry, as the electron theory and some modern ideas on structure seem to place too great a burden on the student struggling with the long medical curriculum.

There are a few faults which call for correction. The author is not playing fair with his readers when on p. 155 he mentions the parachor and dipole moment; whether these are suitable subjects for discussion in such a book might be argued, but no word of explanation of the terms is vouchsafed. Acetoacetic ester is stated to form a sodium compound with the sodium attached to the β-carbon atom, yet the compound is formulated as the sodium salt of the enol. Diazomethane is described as being prepared through methyldichloroamine and no mention is made of the laboratory methods from nitrosomethylurethane or nitrosourea. Despite such minor blemishes the book is one that can be warmly recommended.

The second volume is a shorter version of the first and differs from it chiefly in a briefer treatment of carbohydrates and heterocyclic compounds and in the omission of more than passing references to purines, terpenes alkaloids and proteins. It has many of the virtues of the larger book, but the student will be puzzled when he encounters for the first time the symbol for the semipolar double bond or co-ordinate link and the electron theory without the explanation supplied in Chapter II of the larger work.

Both books are attractively printed and bound.

O. L. B.

Lehrbuch der organischen Chemie. By Dr. Paul Karrer, Professor an der Universität Zürich. Dritte umgearbeitete und vermehrte Auflage. [Pp. xxiii + 922, with 4 figures and 2 plates.] (Leipzig: Georg Thieme, 1933. RM. 34.—paper covers, RM. 36.—bound.)

There is something refreshing in the outlook of this book which makes it different from the ordinary text-book of Organic Chemistry; this is manifested not only in the more lively and interesting manner of presentation but also in the general lay out. In the preface to the first edition the author emphasised his intention of familiarising the student with the methods of synthesising and determining the constitution of compounds. To attain the latter end he has indulged in a very lavish use of structural formulae, apparently with complete disregard for expense of printing but in any case with an extremely satisfactory result. The system of classification adopted is in the main that of aliphatic, carbocyclic and heterocyclic, but it has not been rigidly adhered to where convenience or logical sequence made it desirable to do otherwise; thus in order to emphasise the genetic relationships of the pyrones and indigo to the aromatic compounds they have been treated

with these rather than with the heterocyclic compounds; an additional advantage resulting from this arrangement is that these chemically and physiologically important substances can be introduced to the student at an earlier stage than would otherwise be possible. For the rest the general arrangement follows an extremely logical system which however occasionally leads to rather surprising juxtapositions or separations, as for example the treatment of urea, ureides and purines in distinct sections of the text. The carotinoids, vitamins, hormones and chlorophyll have been specially revised, as might have been expected in view of the great advances in our knowledge of the chemistry of these subjects to which the author's own work has so largely contributed. Individual opinions will naturally differ as to what should be included or omitted in such a text-book as this and some teachers will no doubt cavil while others will rejoice at the omission of any reference to the electronic theory of valency, dipole moments and the like. Features, not as a rule found in books of this type, are an account of the methods of micro-combustion, a fairly full account of Robinson's theory of the phyto-chemical production of alkaloids and an appendix of 23 pages of tables, covering a remarkably wide range of subjects. These include a complete list of substances occurring in coal tar with names of their discoverers, the relative sweetening powers of different organic compounds, a classification of odours, the limits of toleration by human beings of a variety of irritant gases, comparisons of the properties of a number of explosives in addition to a selection of statistical data and illustrations of the appearance and cross-sections of various textile fibres. The book is well printed, it contains a number of illustrations, and can be wholeheartedly recommended as a very instructive and inspiring book; it is no wonder that it should have attained to its third edition no more than five and a half years after its first appearance.

P. H.

Practical Microscopical Metallography. By R. H. Greaves, D.Sc., and H. Wrighton, B.Met. [Pp. xi + 256, with 311 illustrations.] (London: Chapman & Hall, Ltd., 1933. 18*s*. net.)

The unique and invaluable service rendered by metals, from which man has derived incalculable benefit, are due to two essential properties. In the first place, with very few exceptions, metals will alloy freely, producing, in their alloys, new materials with distinct properties from those of the alloying metals, and hence the range of new materials which may be produced is practically unlimited. In the second place, many alloys may have their properties considerably modified according to the mechanical or heat treatment to which they may be subjected. The study of this aspect of Metallurgy, generally known as Physical Metallurgy, is obviously of the utmost importance.

Metallurgists have ascertained that a change of properties in any metal or alloy is accompanied by a change of structure so that a study of structure, or the study of Metallography, is a vital factor towards the understanding of the behaviour of known metals and alloys and the further supply of new alloys for the ever-increasing demand of mankind.

One of the outstanding difficulties in the study of Metallography is the skill that is required to reveal the true structure of metals and the Authors of this book are to be warmly commended on the thorough and clear way in which they have faced these difficulties and given valuable guidance whereby

they may be overcome; previous publications often have been lacking sadly in this respect.

Another distinct feature is the exceptionally high standard of the numerous photo-micrographs which so clearly illustrate the scientific matter of the text; students of Metallography have found, not infrequently, a real difficulty in disentangling the different phases or constituents which may be present in a more complex structure imperfectly photographed and reproduced.

A rather large proportion of the book is devoted to iron and its alloys, and though the importance of this side of the subject is beyond question a fuller treatment of the important non-ferrous Metals and Alloys would be welcome and give a better balance to the whole.

This publication fulfils a distinct and long felt need and undoubtedly will be an essential part of the equipment of all Metallurgists and Engineers concerned with the study and development of Physical Metallurgy.

D. H. I.

GEOLOGY

An Introduction to Geology. By EMERITUS PROF. W. B. SCOTT. Third edition, rewritten throughout. **Vol. I: Physical Geology; Vol. II: Historical Geology.** [Vol. I, pp. xiii + 604, with frontispiece and 264 figures. Vol. II, pp. vii + 485, with frontispiece and 389 figures.] (New York: The Macmillan Co., 1932. 16*s*. net and 14*s*. net respectively.)

As is indicated by the above and ensuing titles a regular spate of geological text-books has set in from America. This is all to the good, for the older books are becoming jejune and desiccated; whilst, on the other hand, a vast mass of new data, new opinions, new ideas, and new theories, requires to be formulated and incorporated, with judicious pruning and selection, into new texts.

Prof. Scott's *Introduction to Geology* also raises the question whether the day of the "one-man" text-book has not passed. Geological science has become so encyclopædic in its range that it is doubtful whether successors to Geikie, de Lapparent, Haug, and Kaiser, are nowadays possible. The one man who, in his versatility and literary power, could have continued the great tradition, the late Prof. J. W. Gregory, is, alas, dead.

The new plan of collaboration between two or more authors, has obvious advantages in these days of necessary specialisation, and it is now being adopted in many German and American publications.

Prof. Scott's book is now in its third edition. The first edition was published as far back as 1897; the second in 1907 had many reprintings the last of which was in 1930. To incorporate the new data that has accumulated in the twenty-five years between the second and third editions it has been found imperative to rewrite the book altogether and to adopt a new order of treatment. The first volume deals with Physical Geology. It begins with a conspectus of the present state of the earth, and goes on to describe igneous rocks and igneous processes. A chapter on diastrophism and earthquakes brings us to the sedimentary rocks and descriptions of the work of surface agencies. Subsequent chapters on the structural features of large stratified rock masses, leads to consideration of the origin of mountain ranges and the processes of metamorphism. The volume ends with chapters on ore deposits and land sculpture.

The second volume treats of Historical Geology. Here Prof. Scott, as a palæontologist, is in his element, and has produced a most fascinating story. A new feature of this edition is a section on Ancient Man. Furthermore, Prof. Scott has made full use of the theory of evolution which, while he was completely convinced of its truth, was not made the basis of the story in the earlier editions.

While it is inevitable that there should be some misprints, mistakes, misstatements, and omissions, the number of these is unusually small considering the length of the book Its literary quality is excellent; the writing throughout is clear, easy, and dignified, and there is no internal evidence that the writer is an American. The very numerous illustrations are mostly photographic. On the whole they are well selected and well produced. A feature of the book is the very large number of British geological photographs, mostly from the British Association collection, which have been used. Readers will be grateful to Prof. Scott for providing separate indexes to each volume instead of the usual comprehensive but irritating single index placed at the end of the second volume. Considering the quantity and quality and neat format of this text-book the price strikes us as very moderate.

G. W. T.

A Textbook of Geology, Part I. Physical Geology. By C. R. Longwell, A. Knopf, and R. F. Flint. [Pp. vii + 514, with 314 illustrations.] (New York: John Wiley & Sons, Inc.; London: Chapman & Hall, Ltd., 1932. 23*s*. net.)

A few years ago the authors of this work assisted in the revision of Part I —Physical Geology—of the well-known *Textbook of Geology* by Pirsson and Schuchert. This book was reviewed in Science Progress (Oct. 1930, p. 353). In the earlier book the authors felt bound to retain as much as possible of Pirsson's method of presentation. The present volume is the avowed successor to Pirsson's work. It embodies much of the organisation and mode of presentation of the material which was developed during the earlier revision, along with much new material, although the order of the chapters has been somewhat changed. The chief features of the new book are: the treatment of weathering as a unitary subject and not under the heading of "Work of the Atmosphere"; the importance of climate in determining the chief soil-types is emphasised; wind action is likewise treated apart from weathering. Modern research in glaciation, petrology and metamorphism has been incorporated in the discussions of these subjects, and late work on seismology, especially on near earthquakes, has been utilised in the chapter on the interior of the earth. Current controversial questions are not treated dogmatically, for "Why should an elementary text give the false impression that most of the Earth's secrets are known?" Subjects, such as discussion of weather and the mechanics of glacier motion, which have no direct bearing on geological history, have been deleted from this edition.

A special word of praise must be given to the magnificent illustrations, notably the serial diagrams, the majority of which are entirely new. The writing is lucid and conforms to literary standards much better than some other American texts. We consider this an extremely sound and able textbook which forms a worthy successor to Pirsson's fine original work.

G. W. T.

A Textbook of Geology. Part II. Historical Geology. By C. SCHUCHERT and C. O. DUNBAR. 3rd edition. [Pp. vii + 551, with 332 figures.] (New York: John Wiley & Sons, Inc; London: Chapman & Hall, Ltd., 1933. 25*s*. net.)

THE second part—Historical Geology—of the original *Textbook of Geology* by Pirsson and Schuchert (1915) reached a second edition in 1924. The present edition has been prepared by Prof. C. Schuchert who is still happily with us, with the co-operation of his junior colleague at Yale, Prof. C. O. Dunbar. This edition has been expressly designed as a text somewhat less advanced and less technical in its point of view than the earlier edition. Prof. Dunbar has approached his task from the pedagogic aspect, whilst the senior author has brought to bear his long experience of original research, his evaluations of new stratigraphical discoveries as they appeared in the literature, and his constructions of palæogeographical maps embodying the most recent available information. The new point of view has necessitated considerable rearrangement and complete re-writing of the material, and the replacement of the majority of the illustrations by new ones.

In this book the history of the Earth from the fiery birth of the planet to the emergence of Man is treated as a great drama; and the details of the story have been ingeniously grouped around relatively few leading principles and conceptions. This mode of treatment, combined with a picturesque and graphic style of writing, has made the story of the earth a series of fascinating episodes in which the high lights and shadows are well contrasted from period to period, and in which the working principle of evolution may be traced as the indispensable thread of historical continuity. Furthermore, the excellent plan of discussing the stratigraphical record of each period after its physical history has first been summarized, has been adopted.

In the previous edition short chapters on biological and palæontological subjects were sandwiched between the appropriate stratigraphical chapters. This method, however, is held to disrupt the continuity of the story too much. and the necessary biological information is now relegated to an appendix of 41 pages under the quaint title of An Introduction to Animals and Plants.

While the stratigraphical details given in this book refer mainly to the North American continent, the rest of the world has not been neglected; and since the treatment of principles is universal in its application the book is almost as suitable for British students as it is for their American colleagues.

G. W. T.

Geology. By W. H. EMMONS, G. A. THIEL, C. R. STAUFFER, and I. S. ALLISON. [Pp. xii + 514, with 478 figures.] (New York and London: McGraw-Hill Book Co., 1932. 24*s*. net.)

THIS is a thoroughly competent and workmanlike text-book, but it is almost devoid of graces of imagination and style. Chunks of geological information have been sawn off from the general stock and then neatly dovetailed together. One can imagine the student plodding through it for examination purposes, but not for pleasure as he might with other texts one could name. The book is intended as a text-book for students taking a "one-semester beginning course." The order of presentation is as follows: Introduction, Nature of Materials that Constitute the Earth, Weathering, the Atmosphere, Ground Water, Gradational Work of Streams, Gradational Work of Snow and Ice, Lakes and Marshes, the Ocean, Sedimentary Rocks, Diastrophism, Vulcanism,

Mountains; their Origin and Structure, Metamorphism, Structures of Rocks, Mineral Deposits, Probable Conditions Within the Earth, a Brief Outline of Earth History. We believe with the authors that this order is pedagogically sound.

The details in the text and the illustrations are mostly good, well selected, and modern, but six pages are devoted to the "Physics of the Atmosphere and Meteorology," subjects which seem to be extraneous to discussion of the geological work of the atmosphere. We fear that the drawing of "volcanic ash" (Fig. 51, p. 60) will convey little or nothing to the elementary student. The term "gradation" is used by the authors and by other American writers to cover "degradation" (wearing down) and "aggradation" (building up), but it is a terminological supererogation which has no geological significance. The statement for instance that (p. 10) "rocks . . . are continually subject to gradation" is meaningless. Rocks are subject to degradation and aggradation, but not to gradation. Valuable lists of references are subjoined to each chapter and there is a full index.

G. W. T.

Text-book of Palæontology. By Karl A. von Zittel, late Professor of Geology and Palæontology in the University of Munich. Translated and Edited by Charles R. Eastman, Ph.D. Vol. II. Second English edition revised, with additions, by Sir Arthur Smith Woodward, F.R.S. [Pp. xvii + 464, with 533 figures.] (London: Macmillan & Co., Ltd., 1932. 30*s*. net.)

The issue of the second edition of Vol. II (Vertebrates—Fishes to Birds) completes the revision of the Zittel-Eastman *Text-Book of Palæontology*, the second edition of Vol. III (Mammalia), revised by Sir Arthur Smith Woodward, having appeared in 1925. We hope that the present volume of this indispensable text-book will be followed shortly by a further revision of Vol. I (Invertebrates), the second edition of which, issued in 1913, now requires bringing up to date.

The present volume conserves the original form and method, but much of it has been rewritten, and it has been considerably enlarged, with many additional figures, to incorporate and illustrate the results of recent work. It is very satisfactory to have in systematic summary the notable researches of Stensiö and Kiaer on the Ostracoderms, and of Broom, Nopcsa, Watson and others on the Lower Tetrapods. It is regrettable that the first results of Säve-Söderbergh's work on the Devonian Stegocephalia of East Greenland and Stensiö's monumental treatise on the British Cephalaspids were published too late for inclusion in this compilation.

J. W.

The Unstable Earth: Some Recent Views in Geomorphology. By J. A. Steers, M.A. [Pp. xiii + 341, with 66 figures.] (London: Methuen & Co., Ltd., 1932. 15*s*. net.)

The subtitle of this book includes the term geomorphology, and while Mr. Steers is, of course, entitled to define this term in his own way as, following its derivation, "that department of physical geography which deals with the form of the earth, the general configuration of its surface, the distribution of land and water, etc," it is as well to point out that the term geomorphology is widely used, especially in America, to denote the science of the evolution of

small-scale land forms, a type of investigation associated in particular with the name of Prof. W. M. Davis. The subject of this book is the form, structure, and movements of the major segments of the earth's crust, a study which is usually called tectonic geology or geotectonics.

The book is divided into two unequal parts: the first four chapters dealing with the major structural features of the earth's surface—the continents and oceans, and the great mountain-systems—and the two final chapters dealing respectively with raised beaches and river terraces, coral reefs and coral islands. The first part gives the impression of being treated, however ably, from the outside, while the second is obviously dictated from inside or first-hand knowledge. This is not to say, however, that the first portion of the book is inferior. On the contrary, it is a first-rate compilation and gives in compact form valuable summaries of recent contributions to knowledge of the structure of the continents, the history of the oceans, and the development of the great mountain ranges, as well as a much-needed digest of the numerous tectonic theories which have recently been formulated under the names of Chamberlin, Kober, Jeffreys, Wegener, Joly, Daly, and A. Holmes.

The second part of the book is concerned with phenomena which depend mainly on fluctuations of sea-level in recent times, in particular the problems of raised beaches, river terraces, submerged forests, and coral reefs. In the latter the author has been helped by his experiences as a member of the Australian Barrier Reef Expedition. Mr. Steers has written an illuminating discussion of the various theories of coral-reef formation. The present trend of opinion, he thinks, is in favour of the subsidence theory, notwithstanding its many weaknesses, a fact largely due to W. M. Davis's re-examination of Darwin's views in the light of the physiographical evidence.

The book is illustrated by clearly drawn diagrams, and has a good index. It will prove most useful to advanced students of geology.

G. W. T.

Igneous Rocks and the Depths of the Earth: containing some Revised Chapters of "Igneous Rocks and their Origin" (1914). By PROF. R. A. DALY. [Pp. xvi + 598, with 190 figures and 3 plates.] (New York: McGraw-Hill Book Co., Inc.; London: McGraw-Hill Publishing Co., Ltd., 1933. 30s. net.)

THOUGH Prof. Daly's theory of the origin of igneous rocks (1914) claimed to be an "eclectic" integrating the soundest parts of various petrogenetic theories then entertained, few petrologists could have been sanguine enough to expect for it an immediate and ready acceptance: opinion was already sharply divided on its main idea—magmatic assimilation. It gained in interest and appeal during the critical years following the publication of Bowen's major theses, and recent progress has raised many of its hypotheses to place among the accepted facts of to-day—without, however, weakening the fundamentals of the differentiation theory which, like Daly's theory, has troubles exclusively its own. Both theories rest on speculative postulates concerning the chemical and physical nature of the earth's interior, where magmas originate.

The new edition of Daly's great work is well abreast of progress. The original text-matter, largely re-written, has been considerably extended, and a change in the subsidiary title acknowledges petrology's dependence on geophysics and cosmogony for data essential to further progress.

Following the plan of the old edition, Part I (new edition) assembles the facts to be explained by theory; Part II re-states the "eclectic" theory, which is applied, in Part III, to a genetic study of the main rock-types grouped in "clans." The relative merits of alternative views are assessed without asperity or dogmatism: debate throughout proceeds in the spirit of Coleridge's dictum that "Truth is a good dog" but should "beware of barking too close to the heels of an error" lest it get its brains kicked out.

The extent to which the new edition reflects contemporary opinion may be gauged by comparing Daly's old with his new list of "classified magmas" (1914, p. 312; 1933, p. 356). Retaining the two primary (sialic and basaltic) magmas, he provisionally accepts a third—the primary peridotite-magma suggested by Holmes. He admits palingenesis, and stresses the principle that selective fusion is merely crystallisation in reverse. His secondary magmas now include palingenetic melts and their differentiates; anatectic granite-magma; the products of gas-fluxing, and various initial syntectics of crustal rocks with either basaltic liquid or "magma more acid than basalt." His deletion of pyroxene-andesite from the listed differentiates of parental basalt seems rather more deliberate than the text-matter on andesites would appear to warrant. Though he agrees that typical andesites are "more easily explained" by syntexis and that belief in a primary intermediate (dioritic) magma must be abandoned, he overlooks some outstanding field-occurrences which support his case, *e.g.* the hybrid diorites, tonalites, etc., of Trégastel-Ploumanac'h and Ronez. He withholds comment on the lamprophyre problem—doubtless with good reason.

This scholarly effort to co-ordinate an enormous number of facts, both old and new, will be accorded a warm welcome by researchers and senior students alike.

A. Brammall.

Explanatory Notes to Accompany a New Geological Map of the Commonwealth of Australia. By Sir T. W. Edgeworth David, K.B.E., F.R.S [Pp. 177, with 10 figures, 11 tables, and map.] (Sydney: Commonwealth Council for Scientific and Industrial Research. London: Edward Arnold & Co., 1932. With map unmounted, 20*s* net; with map mounted on linen and contained in case, 42*s*. net.)

It is well known that Sir T. W. E. David has in hand a monumental work on the Geology of the Commonwealth of Australia (London: E. Arnold & Co.). The present work gives a preliminary short statement and summary of the geology of the continent in the form of explanatory notes to accompany a new geological map. The Explanatory Notes are divided into five sections treating respectively of the physical geology, historical and tectonic geology, economic geology, details of the cross-sections engraved on the map, and a historical review of the geological development of Australia and New Guinea. A vast amount of information has been furnished in this way. The numerous tables of correlation with European time-divisions, of which the tentative character is always emphasised, are extremely valuable features of the book. When their importance warrants it, the igneous rocks of the various systems are dealt with in separate sections.

The geological map in four parts each 42 in. by 34 in., on the scale of 1 : 2,900,000, is a beautiful production worthy to rank beside Bailey Willis's

geological map of North America. Notwithstanding the intricacies of the eastern portion of the map, the colours stand out with perfect clearness. There are still large, geologically-unexplored areas in Western, Central, and Northern Australia which have perforce been left uncoloured on the map. Numerous coloured cross-sections on the margins provide information as to the structure of the continent along certain lines. Tasmania is included as an inset on a larger scale than the main map, and a valuable extension to the north-east covers the mandated territory of New Guinea.

G. W. T.

The Story of a Billion Years. By W. O. HOTCHKISS. A Century of Progress Series. [Pp. x + 137, with 8 figures.] (Baltimore: The Williams & Wilkins Co, London. Baillière, Tindall & Cox, 1932. 5*s*. 6*d*. net)

THIS volume is one of a series designated the Century of Progress Series which has been prepared in co-operation with the Century of Progress Exposition of Chicago to present the "essential features of those fundamental sciences which are the foundation stones of modern industry." Prof. Hotchkiss has treated geology in this book with a light, graceful, and scholarly touch. The story of the earth is ingeniously constructed, step by step, from study of the sediments deposited in a Wisconsin mill-pond. Chapters entitled the Surface Features of the Earth, Origin of the Earth, Age of the Earth, Record of Living Things, Climates of the Past, and the Great Ice Age, thus are made to cover most of the science of geology in an easy, elementary, and popular manner. Conformably with the aim of the series in which this book appears Prof. Hotchkiss concludes with three chapters on the economic and industrial aspects of the science—Geologic Resources We Use, What Geologists have Learned in the Last Century, and What of the Future, all valuable essays which emphasise the importance of the earth sciences to humanity The final chapter discusses on a high plane the future of mankind as affected by geological, geographical and climatic factors. The author is soberly optimistic concerning the future while giving due weight to the often expressed view that disaster faces the race because its material progress has so greatly outstripped its moral and mental advance. This book reaches a high level of expository excellence, and will stimulate both the professional and amateur of the science, as well as the intelligent laymen to whom it is addressed, to greater insight and better appreciation of the possibilities of geology.

G. W. T.

Earth-Lore: Geology without Jargon. By PROF. S. J. SHAND. [Pp. viii + 134, with 4 plates and 33 figures.] (London: T. Murby & Co., 1933. 5*s*. net.)

PROF. SHAND'S new popular book on geology will delight many readers, not least his professional colleagues, for it is full of fresh ideas, phrases, and modes of presentation which will assuredly be of pedagogic value. The book deals mainly with the dynamic and tectonic aspects of the science. It begins with an introduction setting out the adventures of one Adamson who "finds himself on a great raft of earth floating in nothingness." In the first chapter Adamson is instructed in the art of Seeing Things to Scale; in the second he is made to see the Face of the Earth in a novel way—a chapter in which

the author waxes scornful concerning the tetrahedral theory. And so it goes on in Prof. Shand's delightful graphic and pungent, not to say pugnacious, style. Earth sculpture, the sea floor, the book of the rocks, the Creation saga (this an excursus in Victorian rationalism), the age of the earth, the interior of the earth, chimneys in the crust (volcanoes), the problem of mountains, rifts and ramps, the support of the crust, and drifting continents, are the subjects of the remaining chapters. The book contains four excellent plates, some instructive diagrams, a wonderful coloured picture (on the cover) of a segment of the earth showing its probable composition, but no index. This is emphatically a book for Workers' Educational Association and similar popular classes, for it is calculated to arouse enthusiasm and to maintain interest in the science of geology; but it will also enable the ordinary University student to obtain a good conspectus of the subject.

G. W. T.

A French-English Vocabulary in Geology and Physical Geography. By G. M. Davies, M.Sc., F.G.S. [Pp. ix + 140.] (London: T Murby & Co., 1932. 6s net.)

This little book is much less ambitious than the German-English Geological Terminology from the same publishing house reviewed in Science Progress (Jan. 1933, p. 538), but we think it may be even more useful to research workers We are told that its origin was in a thumb-indexed note-book in which all unfamiliar words met with in reading French geological literature were entered. Its form, a simple juxtaposition of the French terms and their English equivalents, the French term being placed first in heavy type, is by far the most convenient and easily used. The scope of the vocabulary is much wider than that stated in the preface, namely geology, physical geography, mineralogy, petrology, palæontology, stratigraphy, and mining, for we have noticed many terms appertaining to zoology, botany, physics and chemistry, as well as verbs, nouns and adjectives commonly used in French scientific literature. Words which differ but little from their English equivalents have been omitted, and for the sake of brevity it has also not been thought necessary to insert all derivatives from a common root. An appendix gives a list of stratigraphical formation names of more than local application with their English equivalents. We have used this vocabulary extensively and are able heartily to recommend it to those who have occasion to read French geological, geographical, and mining literature.

G. W. T.

BOTANY

The Flora of Leicestershire and Rutland. By A. R. Horwood and the late Earl of Gainsborough. [Pp. ccxcvii + 687, with 31 plates and 5 maps.] (London: Oxford University Press, 1933. 35s. net.)

Nearly half a century has elapsed since the Leicester Literary and Philosophical Society produced the last Flora of Leicestershire. That was a work of nearly 400 pages of which approximately half was concerned with the flowering plants and "vascular Cryptogams." In the present Flora the lower cryptogams are entirely omitted, but nevertheless, the text occupies not far short of a thousand pages, which, even allowing for the addition of Rutland, indicates the extent of the work accomplished during the last fifty years.

We owe the present work to the industry of Mr. Horwood and the late Earl of Gainsborough, together with a number of helpers, as well as to the generosity of Mr. C. C. Turner.

For each species, in addition to the usual distributional data, the geological formations, the soils, and the plant communities in which the species has been found, are cited, as well as its altitudinal range.

The flora proper is preceded by nearly 300 pages of introductory matter treating of the meteorology, geology, soils, topography, plant communities and botanical history of the two counties. These sections contain much local information though unduly extended in certain sections and including some matter, such as the page devoted to the origin of the British Flora, of a rather superficial character.

The somewhat hurried preparation of the work for the press, to which Mr. Horwood refers in the introduction, is doubtless responsible for the unfortunate use of the same abbreviation for both marl and marsh soils. The treatment of woodlands in a separate section from that dealing with the natural types of vegetation suggests an implication that was doubtless unintentional, but the reason for the separation of these accounts, both in the sections on Rutland and on Leicester, by accounts of the meteorology is an arrangement difficult to understand. The classification of the plant communities is based on that of *Types of British Vegetation*, which was published over twenty years ago, when the study of plant communities in this country was in its infancy, so that it not unnaturally hardly accords with present knowledge. The classification of Oakwoods into Damp Oakwood, Dry Oakwood and Sandy Oakwood, even as a purely static presentation, is unsatisfactory, and illustrates the difficulties the authors have obviously encountered in attempting to treat dynamic units as static entities. Nevertheless, the inclusion of ecological information is a welcome addition and adds materially to the utility of the flora.

Exclusive of aliens the vascular plants found in the two counties number 2,376, or about 42 per cent. of the British Flora From the point of view of geographical distribution, perhaps the most interesting species is *Tofeldia palustris*, unfortunately now extinct, which formerly occurred in the N.W. corner of the county constituting its southernmost limit for Britain, which is now in north-west Yorkshire. *Vaccinium Vitis-Idæa* still occurs in one locality which constitutes its eastern limit in the midlands, this being a northern species with a diagonally S.W.–N.E. limit from north-east Yorkshire to Devon, though this species formerly grew in Epping Forest.

The small-leaved Elm of the midlands, allied to the Cornish Elm, is here figured and described as a new species under the name of *Ulmus elegantissima*. Of the fifty-three species which have become extinct in Leicestershire during the period over which we have records, those of damp habitats predominate, as in other counties, representing approximately 51 per cent. of the total. Next in order of representation come heath (17 per cent.), woodland (13 per cent.), calcicole (9 per cent.), and cornfield (6 per cent.) plants. Only six species are recorded from Rutland which are not now known to occur there, of which three are wet habitat plants.

The work is excellently produced in a format similar to that of Druce's *Flora of Berkshire* from the same press. The plates include some beautiful photographs of natural vegetation and portraits of some of the notable contributors to the botanical study of the area.

E. J. S.

The Study of Cacti. By Vera Higgins, M.A. [Pp. 164, with 8 plates.] (London: Blandford Press, Ltd., 1933. 7*s*. 6*d*. net.)

To the increasing number of those who cultivate these bizarre plants this work can be confidently commended as a concise guide to their classification and mode of cultivation, whilst the information furnished regarding their morphology and physiology should greatly enhance the pleasure which cactus cultivators derive from their hobby

The rather comprehensive title is perhaps a trifle misleading since certain aspects of their study, such as their peculiar morphology and the debatable question of their respiratory processes are but briefly treated.

Descriptions are furnished of all the 126 genera and representative species of sixteen of these are admirably portrayed in the photographs reproduced in the plates. It would have materially added to the usefulness of these if they had been numbered and references given to them in the appropriate places in the text.

The greater part of the handbook is devoted to taxonomy, nomenclature, and the generic descriptions Chapters are also furnished on the geographical distribution, the uses of cacti, methods of cultivation, and general structure.

The manner of presentation neither errs in being too technical nor too popular, and this book thus fills a definite gap in horticultural literature.

E J. S.

West African Agriculture. By O T Faulkner, C.M G., B.A., and J R Mackie, M C., B Sc [Pp viii + 168, with 1 illustration.] (Cambridge University Press, 1933. 8*s* 6*d*. net.)

This is a valuable book. It deals mainly with Nigerian conditions of which the authors have detailed knowledge. The introductory chapter is of special interest not only to those directly concerned with agriculture but to a much wider public. The essential difference between West African and, say, British agricultural conditions is that in the latter the aim is to increase the profit per acre, whereas in the former "the thing which really counts is labour," since the farmer and his family do practically everything by hand. This is their justification for using methods that give the maximum return for the minimum of effort—methods which are mistakenly described as inefficient and out-of-date by those who do not appreciate their fundamental justification.

The authors draw attention to the bearing of this on the policy of development of such regions. This should be—and, wisely, now is—to base all improvements and advances on and within the economic framework of the native agriculture. They point out that this policy will ultimately lead also to the maximum production of raw materials for export.

The work of the agricultural department has already thrown into relief some important scientific problems of tropical soil behaviour, such as a marked response to nitrogen in quite small dressings of organic manure, and a frequent poor response to phosphate manures. Further work on these problems is very desirable, since our present knowledge of biochemical actions in soil is based largely on what happens in temperate climates. It is of interest to note that the puzzling inconsistencies of green-manuring (crops grown for ploughing-in as organic manure) which are familiar to agriculturists in this country, are also observed in the light soils of Nigeria: this aspect of soil-

fertility management seems to possess a healthy disregard for text-book rules.

Some valuable comments are made on the question of "shifting cultivation"—the long-established practice of cropping intensively for a few years a piece of land cleared from bush and then allowing it to revert to bush to regain its fertility. The process obviously cannot serve when the population density exceeds a certain level, and some permanent substitute involving continuous farming of the same area has to be found. The problem can be stated in simple terms: it is merely one of finding a supply of manure which, within the labour and economic organisation of the country, will give a profitable return The solution of the problem, however, is not easy, and there are at least three distinct sets of conditions to meet. In the Northern Provinces, where cattle can be kept, it is feasible to consider an extension of the combined animal and arable husbandries, known as "mixed-farming"; in the south-western regions, green-manuring offers possibilities; but for the poor acid soils of the Delta Provinces, with their high rainfall and dense population, measures have still to be devised.

The second part of the book is devoted to detailed accounts of individual crops, especially those such as the oil palm, cocoa, rubber, and coconuts which supply raw materials for export. Finally, there is a short chapter on livestock.

B. A. K.

Recent Advances in Agricultural Plant Breeding. By H. Hunter, Hon. M.A. (Cantab.), D.Sc (Leeds), Plant Breeding Institute, School of Agriculture, Cambridge, and H. Martin Leake, M A., Sc.D. (Cantab.), formerly Director of Agriculture, United Provinces, India, and Principal of the Imperial College of Tropical Agriculture, Trinidad. With a Foreword by Sir Rowland H. Biffen, M.A., F.R.S. [Pp x + 361, with 16 plates.] (London: J. & A. Churchill, 1933. 15s net.)

The problem before our authors here was a difficult one. For obviously, although there are general principles along which advances have been made in the subject, the special interest is in the application of these principles to particular cases; as a consequence of this any general statement of advances must necessarily be a short one and the main portions of the book be taken up with the discussion of progress in the breeding of individual plants. This method might easily produce a dull book, and it is much to the authors' credit that this is far from being the case.

The crops are treated individually in two series—those of temperate regions and those of sub-tropical and tropical regions. In the description of each plant there is a discussion of its origin and an attempt to give a well-rounded-off account of the plant itself, its uses and the methods used to produce the kind of varieties required. Matters like the details of pollination, conditions of pollen growth, viability of pollen, causes of sterility and semi-sterility, problems of resistance and immunity, chromosomal constitution and basic number of chromosomes and effect of stock on scion are all dealt with.

The work will prove useful to all interested in genetics, cytology and mycology as well as those working in the subject.

E. M. C.

ZOOLOGY

Text-Book of General Zoology. By W. C. CURTIS AND M. J. GUTHRIE, with the collaboration of K. R. JEFFERS. Second edition. [Pp. xv + 588, with 438 figures.] (New York: John Wiley & Sons, Inc. London: Chapman & Hall, Ltd., 1933. 23*s*. net.)

THE present edition of this book, the first edition of which appeared in 1927 and was reviewed in these pages, has been completely reorganised and largely rewritten The alterations greatly improve the value of the book and render it much more complete, since several chapters have been added dealing with phyla not included before The number of illustrations has also been increased by 130. Almost half the book is devoted to the Chordates, their structure, functions and natural history, and to special branches of zoology, to which they are used as an introduction, such as genetics, cytology, histology and embryology. The greater part of the remainder is devoted to the invertebrate phyla. The last chapter deals with evolution. An extensive glossary of terms and an adequate index enhance the usefulness of the book This text-book approaches the subject in a stimulating manner, and is remarkably comprehensive for its size. The fact that the method of approach, like that of many American text-books, is very different to that usually adopted in this country may detract from its usefulness here. It is less formal than most British text-books, but that is by no means a disadvantage in itself. The production is excellent and the binding is said to be covered with cloth impregnated with pyroxylin, which is consequently waterproof. The advantage of a binding that would resist being soiled by use in laboratory conditions should be appreciated by many.

F. W. R. B.

Laboratory Directions in General Zoology. By W. C. CURTIS, M. J. GUTHRIE and F. H WOODS. Second edition. [Pp. xxxii + 164, with 60 illustrations.] (New York · John Wiley & Sons, Inc. London: Chapman & Hall, Ltd., 1933 9*s*. 6*d*. net.)

THE first-year course in Zoology at the University of Missouri differs in several respects from the conventional introductory courses in this country. Their very stimulating laboratory text-book begins with an account of the Frog, and then passes to a surprisingly complete review of the invertebrate phyla, taken in ascending order. In each group, one or more types are first studied in detail, and then specimens are examined to show the structural range and main outlines of classification of the group. Stress is laid throughout on the observation of the living animal (for instance, when studying echinoderms the students carry out artificial fertilisations of sea-urchin eggs), and there are a number of physiological experiments and demonstrations, especially in the early part of the course.

To a Londoner, these are welcome innovations. To make way for them, since the course has to be done in a year, much of the matter included in the usual British first-year syllabus is omitted. Thus, only one vertebrate type, the Frog, is dissected, and although demonstration specimens of the other vertebrate classes are shown, there is no detailed comparative anatomy. Again, the embryology is limited to the simplest and most significant points. The result is that the book is quite useless as a cram for present-day first-year examinations in this country, and perhaps not so good as a preliminary drill,

for those students who are going to specialise in zoology, as some of the classical texts. As a course for those who are doing only one year of zoology and intend to proceed to other sciences (including medicine) it gives an immeasurably better bird's-eye view of animal biology than any other practical book known to the reviewer.

G. P. W.

Modern Theories of Development. An Introduction to Theoretical Biology. By L. v. BERTALANFFY. Translated and adapted by J H. WOODGER. [Pp x + 204.] (London : Oxford University Press, 1933. 8*s*. 6*d* net.)

THIS book contains a discussion of the nature of living organisms and the methods by which they should be studied The science of embryology is used for illustration of the argument and although the author disclaims the intention of writing a text-book of experimental embryology, yet the result is, incidentally, a very readable account of recent advances in this subject.

The thesis may be indicated by summarising the very valuable formulation which is given of the possible implications for biology of Heisenberg's Indeterminacy Principle. It is possible that "in organisms the (physical) 'microscopical' fluctuations do not cancel one another, but that they are transferred to more and more extensive regions of the system, and so lead to macroscopical departures from the physical, statistical probability of the events " It would seem that if indeterminacy affects biological hierarchies in this way then the laws of thermodynamics will not always hold for the whole system, and, since there is no evidence of this in the behaviour of any living system which has yet been accurately studied, most biologists would probably draw the conclusion (which is not ventured upon by the author) that organisms are not indeterminate in this sense of the word.

There is, however, another sense which he adopts : "In order to determine an individual biological process completely we must know *all* the partial processes in the organism concerned upon which the former is dependent. This, however, is impossible, because just the same holds for each of the other partial processes and our procedure becomes circular ". Hence we can either treat the individual processes in isolation physico-chemically, in which case our account will only be approximate, or we can ". . . define the total event in the organism with one stroke by means of an integral law (this, in our opinion, is the essential biological problem)."

All will agree that for many purposes organismic concepts (gene, chromosome, reflex, etc.) and the laws relating to them are absolutely necessary for biology, but at the same time many biologists will be unwilling to admit that the possibilities of analysis along physico-chemical lines are as limited as Prof, Bertalanffy suggests. For instance, he considers that biology has accumulated sufficient evidence to show that study of the individual processes and their interactions in living systems *can never* give a complete account of their most characteristic feature, namely, the evolution and maintenance of organisation. In fact, he rejects the selection theory and categorically denies that it will ever be possible to synthesise a system showing vital properties.

The study of the relation of process to form is only just beginning, both in physics and biology, and it seems unnecessary to relinquish it at a time like the present, when field theories such as those of Child and Gurwitsch, combined with the analysis of genic action provided by such an extension of

Goldschmidt's theory as Huxley has recently provided, give us a glimpse of the way in which quantitative differences, dependent in the long run on the environment, produce qualitative differentiation. It seems that we are within sight of a biological theory having just that generality, beauty and elegance whose absence from most of biology the author deplores.

But whatever may be the answers to these problems, the merit of this book is that it directs attention to subjects which are too often avoided by working biologists. It questions the capacity of the method of physicochemical analysis to yield the sort of information which the biologist requires and concludes that the real problem for biology is to give an exact account of the ways in which living organisms behave, using any technique which is found to be convenient.

J. Z. YOUNG.

The Mechanism of Creative Evolution. By C. C. HURST, Doctor of Philosophy of the University of Cambridge; sometime Fellow Commoner and Research Student of Trinity College, Cambridge, Fellow of the Linnean Society of London. [Pp. xxi + 365, with a frontispiece and 199 figures.] (Cambridge, at the University Press, 1932. 21*s.* net.)

DR. HURST has set himself a very difficult task "a gathering together of the multitudinous facts which go to make up the genetical story of creative evolution." It may be said at once that we are provided here with a well-arranged and very clearly expressed account of the subject written from the genetical and cytological points of view.

The earlier introductory chapters and the chapters dealing with Chromosomes and Species, mapping the genes, translocation, polyploids, transmutations are, as one would expect, admirably done. When the latter more theoretical portions of the book are considered one cannot help feeling that a very difficult matter has been made to appear comparatively simple; the emphasis on possibilities makes them appear as probabilities or something more.

The gene is treated as the unit of life, building up something more and more complicated, and a progene is postulated. What follows is highly speculative and seems to adopt a too optimistic view of the implications of the work already accomplished in evolutionary studies.

There are a few misprints, but a more important matter is the presence of statements here and there which are likely to give a wrong impression, *e.g.* on p. 52, where only the Taphrinaceæ are accredited with two pairs of chromosomes, but which might easily be interpreted to mean that all fungi do so, and on p. 302, where the suggestion seems to be made that there is a nuclear exchange during conjugation in Spirogyra.

The general get-up of the book has been extraordinarily well done, and the illustrations well chosen, drawn clearly to a good scale and admirably arranged.

E. M. C.

The Senses of Insects. By H. ELTRINGHAM, M.A., D.Sc., F.R.S. [Pp. ix + 126, with 25 figures.] (London: Methuen & Co., Ltd., 1933. 3*s.* 6*d.* net.)

THIS is another volume in the series of monographs on biological subjects being published by Methuen, in itself an ample recommendation.

In the present volume Dr. Eltringham gives a masterly account of the senses of insects. After a brief chapter on their nervous equipment, he gives an account of the insect eye followed by a chapter on vision or the optical performance of the compound eye. Next colour vision is considered. In this chapter the author deals with some of his own experiments regarding colour appreciation in butterflies In the fifth chapter the tactile sense is discussed followed by one on chordotonal and tympanal organs and the auditory sense Next there is a summary of the evidence for the existence in insects of olfactory and gustatory senses. In the subsequent chapter he explains the structure of various forms of sensillæ which may be involved in one or both of these senses. In this connection frequent reference is made to the work of Snodgrass Some sense-organs, for example, Johnston's organ, of uncertain function are then briefly noted. Finally there is a brief concluding chapter, together with an 8-page bibliography and an adequate index.

Naturally in a book of this nature one expects to find many references to investigations by contemporary as well as previous workers. In this respect this volume is very satisfactory and it should serve as a valuable introduction to the subject. It is also probable that men of science will find the book a valuable "refresher" if not actually a stimulus to delve more deeply into the subject. Dr. Eltringham has written in an enticing manner and is to be congratulated on producing such an attractive account of this subject. Books covering this field have been scarce and this new addition most decidedly fills a gap.

H. F. B.

Sex Determination. By F A. E Crew, M D., D.Sc., Ph.D. [Pp. ix + 138.] (London: Methuen & Co., Ltd., 1933. 3*s*. 6*d*. net.)

This addition to the admirable series of Monographs on Biological Subjects which are being published by Messrs. Methuen & Co. provides a very clear account of the well-known principles of sex determination. Though the theory of sex determination has undergone comparatively little modification in recent years the author has managed to introduce some new material into this account. The scope of the book is restricted to the cytological and genetical aspects of the subject and omits the problems concerned with the development of the sexual characters. The popular appeal of the book would in our opinion have been enhanced by the inclusion of a few figures.

F. W. R. B.

Experimental Analysis of Development. By B. Dürken. Translated by H. G. and A. M. Newth. [Pp. 288, with 120 figures, including 14 plates.] (London: George Allen & Unwin, Ltd., 1932. 14*s*. net.)

The appearance at the present time of an English translation of this important work is very welcome. The recent rapid advances in "Entwicklungsmechanik" and the sharp contrast of the resulting conceptions of the organism, with conceptions from other branches of biology, such as, for example, physiology and genetics, have awakened general interest in the subject.

The book, which appeared in German in 1929, provides a very readable account of the major problems of "experimental embryology." Although

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it is not that there is so much interest but that there is too little intelligent interest. History has abundantly demonstrated that the state of nutrition has a profound influence not only upon physical health but also upon manners and morals. One of the great religious movements has recognised this connection in its slogan "Soup, Soap, Salvation," and a somewhat similar idea is expressed in the French proverb "Ventre affamé n'a pas d'oreilles."

A really standard book on food and dietetics such as the one under review should therefore appeal to a large public; when it is associated with the name of Hutchison there is understandably already a large number of persons whose interest is engaged. For all kinds of facts about feeding and the various articles of diet, their food value, their cost, their mode of preparation, their history, their economic value and so on, one turns naturally to "Hutchison." Those who enjoy and those who prepare food will find in it a mine of information. Chapters such as those on the different kinds of bread and their preparation, the properties and ways of making of cheese or the one on meat soups, beef extracts, beef juices, beef-teas and beef powders are examples of the happy mingling of theory and practice, all savoured with the salt of humour.

The vegetarian as well as the man who eats his mixed meal will find his needs considered, though the latter will realise that from the dietetic standpoint he is regarded as the wiser person. Beverages, including tea, coffee, cocoa, alcohol and malt liquors have their chapters discussing their history and their effects upon digestion and metabolism. There are accounts of various artificial and pre-digested foods and special chapters deal with the effects of the different ways of cooking and with "cures" and "systems."

In fact, it is "Hutchison" for so many years in this and in other countries *the* book on dietetics, brought up to date by collaboration with Prof. Mottram, himself the author of entertaining writings on this matter of food. Since its publication in 1900 there have been fifteen printings and seven editions. Such facts speak for the value, popularity and reputation of this book, which should certainly be maintained and even enhanced by this latest edition, which it is sincerely hoped will add to the number of its readers.

W. C. C.

An Outline of Immunity. By W. W. C. Topley, M.D., F.R.C.P., F.R.S. [Pp. viii + 415, with 37 figures.] (London: Edward Arnold & Co., 1933. 18*s*. net.)

Resistance to infection is a topic of paramount importance to animals and plants and it may well be presumed to have played as considerable a part in their past history as it does in their present lives. It is achieved or attempted in a variety of ways—racially by a high capacity for reproduction, individually by preventing the ingress of the parasite, by expelling it from the body altogether or by rendering it ineffective either by the primæval method of phagocytosis or by the action of the antibodies which birds and mammals have learned to make so aptly. Prof. Topley has written a very good and refreshingly original account of the subject as it appeals to those who are particularly interested in the applications of immunity to human medicine and hygiene: his style is perhaps a little prolix but he covers a good deal of ground and uses his facts as *puncta* in a critical argument instead of throwing them at us naked. The book is easily the best

of its kind which is available and it will be of great value to the specialists for whom it is framed: the last four chapters deal with the practical applications of the antigen-antibody reaction and there is a useful summary of the work on herd immunity with which Prof. Topley has been so intimately concerned. But there is no discussion of resistance as a problem in comparative pathology though the author himself says that this is the "only sound basis" of approach: his work is in consequence of less moment to the general biologist.

A. E. B.

Maternal Mortality and Morbidity: A Study of Their Problems. By J. M. MUNRO KERR, M.D., F.R.F.P.S. (Glas.), F.C.O.G. [Pp. xviii + 382, with maps, diagrams, charts, skiagrams, and hospital plans.] (Edinburgh: E. &. S. Livingstone, 1933. 25*s*. net.)

THE subject of maternal mortality and morbidity has attracted increasing attention of recent years both on humanitarian and sociological grounds. That, despite advances in medical science and practice, the mortality from puerperal causes should still be represented by the figure for England and Wales of 4 2 per 1,000 births (years 1925–30) is an arresting fact as human tragedy especially in view of the youth of many of the victims. Sociologically the subject is of importance having regard to the falling birth-rate, and the fact that the victims are potential future mothers, and that the puerperal mortality may be associated also with infant mortality. For such reasons the subject has assumed pre-eminence as a problem of public health.

The statistics of the Registrar-General show no substantial decline in puerperal mortality: thus the rate for the years 1855–64 was 4 7. As is pointed out, however, by Prof. Kerr, this comparison must be made with qualification, and due regard must be given to advance in medical knowledge, increased accuracy of certification, and the more scrupulous attribution of the fatality to the puerperal state. A crude statement that mortality has not diminished should not therefore stand, but the fact remains that there continues a high rate. There is also evidence that, under certain systems of domiciliary and institutional service organised in this country, the rate is very substantially reduced, and also that a lower rate may prevail in other countries. International comparisons must be made with caution, but it is agreed that the statistics of Holland are comparable with those of this country, and they show a rate of 2·98 (years 1925–29). A reduction of mortality considerably below the present figure should therefore be possible. Not one, but many factors are, however, involved so that the problem is not simple; indeed it is, in some respects, elusive. For example, the gross causes of septic infection such as operated at the time of Semelweiss are no longer potent, the medical profession has been trained in antiseptic ritual, the "handy woman" has to a large extent been displaced by the trained midwife, but sepsis still exacts a heavy toll and occurs with a surprising frequency where there has been a minimum of interference: the final word on puerperal sepsis has not yet been said.

In this carefully documented work Prof. Munro Kerr has set out the problem and his suggested remedies. The book contains a wealth of statistics local, national, international, but the possible fallacies of mere statistics are adequately realised and careful analysis of figures is made. A full presentation is given of the pre-natal and intra-natal factors which influence

mortality—the toxæmias, abortion, obstetric complications, sepsis. The problem indeed is very adequately portrayed. The solution Prof. Kerr finds in perfected ante-natal supervision, improved midwife status, efficacious ritual in domiciliary confinements, and the transfer of all but the simplest of obstetric complications to hospitals with highly specialised staff. In short he sets out a perfected organisation. The success of such organisation postulates the co-operation of obstetric specialist, public health administrator, medical practitioner, midwife, and last but not least the pregnant woman, and such co-operation may not be easy of attainment. Economic considerations also cannot be ignored. The provision of institutional treatment for 15 to 20 per cent. of pregnant and parturient women would involve a large increase in existing accommodation and the proposal would require consideration not only in its immediate aspect but in relation also to the pressure for improvement in other public health services.

It is not to be expected that, amongst all of the many interested persons, there will necessarily be complete agreement with the full details of Prof. Kerr's proposals. They will profit, however, by having the problem so adequately surveyed and an ideal so thoroughly expounded. This comprehensive study merits and will repay careful consideration by all concerned with the subject investigated.

PHILOSOPHY AND HISTORY OF SCIENCE

Prout's Hypothesis. [Pp 58.] (Edinburgh: Oliver & Boyd, for the Alembic Club, 1932. London Agents: Gurney & Jackson. 2*s*. 6*d*. net.)

THIS, the latest number to be added to the well-known series of Alembic Club Reprints, includes the two papers published anonymously by Prout in 1815 and 1816 in Thomson's *Annals of Philosophy*, the relevant sections of Stas's paper of 1860, omitting analytical details but giving his general remarks and conclusions on Prout's hypothesis, and Marignac's commentary on Stas's paper. The historical introduction (pp. 5–24) is in itself a contribution to the history of chemistry, and includes extracts from the works of Thomas Thomson, Meinecke (often forgotten in this connection by historians of chemistry), Bischof, Daubeny and, finally, Crookes and Aston: and the references given provide a valuable bibliography for those interested in the history of a hypothesis that has always proved of unfailing attraction to chemists.

Stas was thoroughly satisfied that his analyses had shown that "Prout's Law" was "a pure illusion," but Marignac, despite his admiration for the magnificent experimental accuracy of Stas's analytical researches, could not agree with this verdict. Although concluding that any possible future improvement in analytical methods was not likely to produce results showing any greater accordance with Prout's Law, Marignac maintained that each atomic weight must be determined "by several absolutely independent methods, based on the analysis of a number of compounds altogether distinct from one another," since, otherwise, it was the accuracy with which the analyses were made, and not the soundness of the method, that was confirmed. Moreover, he did not regard it as proved beyond doubt "that many compounds do not contain, constantly and normally, an excess of one of their elements" and, in his discussion of this point, he distinctly harked back to

Berthollet's theory of affinity. For these reasons, therefore, Marignac could not agree that the divergences from Prout's Law were not due to "the imperfect character of the experimental methods." This apart, however, and assuming that Stas's results were exact, he objected to the conclusion "that Prout's Law is nothing but a pure illusion, and that the elements are entities necessarily distinct": rather, he argued, Prout's Law resembled the laws of Mariotte and Gay-Lussac in being an approximate law, probably the normal law, divergences from which were due to "certain disturbing influences, whose effect we shall perhaps also be able at a later date to compute." And here he was led to a remarkable anticipation of the modern theory of the "packing effect": "Could we not suppose," he queried, "that the cause (unknown but probably different from the physical and chemical agencies familiar to us) which has determined certain groupings of the atoms of the sole primordial matter so as to give rise to our chemical atoms, by impressing on each of these groups a special character and particular properties, should not at the same time have exercised an influence on the manner according to which these groups of primordial atoms would obey the law of universal attraction, in such wise that the weight of each group might not be exactly the sum of the weights of the primordial atoms composing it?"

This reprint is a welcome addition to the series.

D McKie

Science and Superstition in the Eighteenth Century. By Philip Shorr, Ph.D. [Pp. 82.] (New York: Columbia University Press, 1932. London: P. S. King & Son, Ltd. 7*s.* 6*d.* net.)

Dr. Shorr here studies the treatment of science in Chambers's *Cyclopædia of Arts and Sciences* (London, 1728) and Zedler's *Universal Lexicon* (Leipzig, 1732–50) in order to discover to what extent the scientific advances of the seventeenth century had affected the general thought of the first half of the eighteenth century and how much of the old and occult science and superstition was carried into the new age.

The *Cyclopædia* treated the history of astronomy very briefly; gave a fairly full and competent account of physics, except in the article on Light where, although Newton's corpuscular theory was dealt with in detail, Huygens's wave theory was not even mentioned; described chemistry in terms of alchemy, pharmacy and Aristotelian philosophy; gave a good account of botany; and treated medicine very incompetently.

The *Lexicon* in its historical treatment of astronomy was unduly biassed towards renaissance workers and neglected their forerunners; pictured scientific method as inductive and viewed the rôle of experiment accordingly; omitted much historical matter in physics, but displayed a sound scientific attitude in discussing its various branches; dismissed chemistry in 1,000 words, but found room for 10,000 words on the philosopher's stone and alleged that there was much evidence for transmutation; summarised the progress of botany in the seventeenth century, retaining much that was medieval; and wrote of medicine as dominated by Galenic theory.

Both retained much of the science and the superstition of earlier centuries. Their greater scepticism in some directions is nullified by their credulity in others, and there is little to choose between them. The *Lexicon* put theology first, the purpose of science being to combat atheism and to prove the divine nature of things: the *Cyclopædia* was free from this, since Chambers was a

free-thinker. Chambers had very little to say about the devil, except to quote the *bon mot* that the Ethiopians painted the devil white to be even with the Europeans who painted him black: on the other hand, the *Lexicon* made the devil very real and allowed as much space (10,000 words) to a discussion of his nature and powers as to the subject of comets. And, of course, the *Lexicon* repudiated Spinoza as the patriarch of all atheists.

In conclusion, Dr. Shorr says: "Hence we must conclude that the scientific tendency, although somewhat obscured by the persistence of occult science and superstition, is already there, gradually shedding its pseudo-scientific skin, only not so rapidly as we might be led to believe from a casual examination of the results of scientific progress in the seventeenth century."

Dr. Shorr has carried out valuable work on a very interesting period; and it would be still more valuable if his references were not so frequently second-hand. Further, Boyle did not preach sermons: he established a fund for others to preach them.

D. McKie.

Modern Chemistry: The Romance of Modern Chemical Discoveries. By Frederick Prescott, M.Sc., Ph.D., A.I.C. [Pp. xiii + 370, with 39 plates and 42 diagrams.] (London: Sampson Low, Marston & Co., Ltd., 1932. 12*s*. 6*d*. net.)

Dr. Prescott, writing for the intelligent general reader alive to the importance of chemistry in our national life, here gives an account of the more important and interesting chemical discoveries and their applications. His book treats of the scope and development of chemistry, the atom, the chemical elements, radium, electro-chemistry, metals and alloys, fuels and illuminants, the nitrogen problem, explosives, cellulose products, dyes, fermentation and drugs. The chapters on metals and fuels are particularly good. The book is well written and illustrated throughout and, as a popular work on chemistry, is one of the best of its kind. It can also be recommended as supplementary reading for students of chemistry in schools and colleges.

Dr. Prescott is mistaken in supposing that Nobel's discovery of dynamite was accidental. As shown in the recent biography, Nobel experimented with various solid absorbents and found that kieselguhr was the most suitable.

D. McKie.

Remembering: A Study in Experimental and Social Psychology. By F. C. Bartlett, M.A., F.R.S. [Pp. x + 317, with 3 plates.] (Cambridge: University Press, 1932. 16*s*. net.)

The connecting link between the first twelve chapters of this singularly interesting and suggestive study of human memory, giving a detailed account of the experimental investigations carried out by the author over a number of years, and the remaining seven chapters, in which he examines the extent to which social factors can influence the mechanisms of memory, is the very original theory of remembering to which his researches have led him. This theory is based on the results of experiments, not only upon remembering and imaging, but upon perceiving also; for, as Prof. Bartlett points out, "perceiving, recognising, recalling, are all psychological functions which belong to the same general series. We must begin our study of the last

two, not from a consideration of the instances in which they alone occur, but from an investigation of the prior perceptual process." Indeed, there is a common element running through them all; and it is in part this element that is disentangled and worked into the theory in question—a theory that cannot adequately be presented, though it may perhaps be indicated, in a brief review.

For Prof. Bartlett remembering is a biological function which is determined by past experiences and reactions. But it is not to be conceived as due to "memory traces" which become reactivated. Rather is it due to the operation of the past as an organised mass of "schemata" which influence present reaction. These "schemata" are conceived somewhat on the lines of Head's conception, similarly named, which he invoked to explain awareness of postural position and change.

Given, relatively low in the scale of development, a schema, this would tend to operate in serial (chronological) order, which biologically would be wasteful. Ascending the scale, as sensory avenues multiply and reactions become diversified, schemata already active may be checked or facilitated by the arousal of others But how? Prof. Bartlett suggests that the organism at this level can "turn round upon its own 'schemata' and construct them afresh." At this point consciousness emerges. We can "go direct to that portion of the organised setting of past responses which is most relevant to the needs of the moment." And this possibility is due to "attitudes" that enable us to select the material from which we construct what we perceive and what we recall. "Remembering is a constructive justification of this attitude." But more is involved than this. Outstanding details of "schemata," determined by interest, tend to arise as images or verbally, and so form the nucleus round which the construction is built up. This thesis involves a discussion of "meaning," to which an interesting chapter is devoted.

The most novel application of his theory of remembering, and probably the one regarded by the author as the most important, concerns the social determination of memory in the individual. This raises the problem of social, or group, memory, and the fate of elements of culture when introduced from one society to another. Based upon an exceedingly ingenious experiment (serial reproduction), a clue is discovered to some of the labyrinths of anthropology and ethnology; and this clue is followed up in several brilliant, if somewhat speculative, chapters.

"Remembering" is not only a valuable contribution to psychology, but indicates also a new method of field investigation which should yield rich results to workers in allied sciences.

F. A.

Man and Metals. A History of Mining in Relation to the Development of Civilisation. By T. A. Rickard, A.R.S.M., D.Sc., Consulting Engineer to the United States Bureau of Mines. [2 vols. Pp. xiii + 506, v + 562, with frontispiece, 93 illustrations and 15 maps.] (London: McGraw-Hill Publishing Co., Ltd., 1932. 50s. net.)

Dr. Rickard was led to write this book because his friend and former fellow-student, Mr. H. G. Wells, did not pay due regard in *The Outline of History* to the part that mining and metallurgy have played in the growth of civilisa-

tion. These volumes, therefore, written by such an outstanding and able authority, remedy a defect in the *Outline* that was obvious to all scientific readers; and it is not too much to say that the author often wears the Wellsian mantle as if it were his own and that on occasions, as in the paragraph on pp. 114–15, he fairly struts in it.

Dr. Rickard opens with a brief account of the history of civilisation and follows this up with a much lengthier treatment of the ages without metal, the preliminary stages of human culture, showing how "civilisation did not begin until metals became the material of tools, implements, and machines" and that "by aid of metals man emerged from savagery." He then devotes a long chapter to the early use of the metals and another to the gold and copper mines of the ancient Eygptians, followed by an account of the activities of the Phœnician metal-merchants. Next he discusses the problem of the Cassiterides or Tin Islands and, after a thorough scientific examination of the geological, geographical and historical evidence, he identifies these islands with the southern parts of Cornwall and the island Ictis of Diodorus Siculus with St. Michael's Mount. Then follow three chapters of great interest dealing with mining in classical antiquity and describing the Athenian silver-mines, the Roman mines in Spain and Italy, and the Roman lead-mines in Britain.

The author begins his second volume with a general account of the mediæval mining of metals, and then proceeds to describe the customs and laws of the mining communities down to recent times with many regrets for the passing of that grand old adventurer, the "free miner," and his replacement by the "hired mechanic" As he says, the democracy of the nineteenth-century mining-camps "was one that put Athens to shame." The next chapter deals with the Conquistadores and the despoiling of the New World by Cortes, Pizarro and others, a record of dauntless courage and revolting cruelty; and here he shows how Cortes in a brief seven months conquered Mexico with a mere 450 undisciplined, greedy, quarrelling ruffians, lured on by their intrepid leader's promises of gold, glory and Indian women. These and similar piracies provided a fresh supply of monetary metal that enabled Europe to go forward when the opportunity for commercial and industrial expansion arrived and, as appears from a quotation on p. 706, led to that almost miraculous event of two economists being simultaneously in agreement.

The succeeding chapters deal with the great mining adventures and "gold-rushes" of the latter half of the last century, the use of coal, the first use of iron and its application in industry and the history of mining in South Africa.

Dr. Rickard has here made a notable contribution to the history of science: he writes everywhere with scientific and scholarly accuracy and his criticisms are precise. He is always alert to the unflagging human interest of his subject: and he points out that the perversity of mankind has turned the blessing of metals into a curse and asks whether we shall mend our ways or go with the Gadarene swine, since our civilisation "is menaced by the misuse of the very products that were essential to its advancement."

There are a few minor errors: "Edward the Confessor" (p. 602) should read "Edward I"; and "Germany" (p. 911, line 7 from foot) should read "France."

D. McKie.

MISCELLANEOUS

Thrills of a Naturalist's Quest. By RAYMOND L. DITMARS. [Pp. xii + 268, with 46 illustrations.] (New York: The Macmillan Co., 1932. 18s. net.)

LATELY there has been a spate of popular literature on "animal men"; but this volume will be of more interest than the rest to the zoologist because of the world-wide repute of the author. It is always pleasing to hear an enthusiast on his own group; but the author's reminiscences are by no means confined to reptiles. There are plenty of amusing stories, like the one about the bear-cubs whose ears were to be painted with a villainous decoction of areca-nut to prevent them sucking them; while the keeper's back was turned they ate the whole bucketful!

The book gives a good idea of the wealth of the reptilian fauna of the United States. Of particular interest to the zoologist is the fact than any snake addicted to cannibalism is recognised on sight and avoided by other snakes, even though they may come from the other side of the globe and have never met a member of the species before.

LARREY H. JACKSON.

Primitive Arts and Crafts. An Introduction to the Study of Material Culture. By R. U. SAYCE. [Pp. xiii + 291, with 58 illustrations] (Cambridge University Press, 1933. 8s 6d. net.)

IN this short volume the author surveys mankind from China to Peru with regard to the material culture, his object being to give a general idea of the principles involved and the problems presented in this branch of anthropology. He emphasises very strongly the differences in culture caused by climate or other natural conditions beyond human control, and instances the "fly-belts" in Africa, where the inhabitants are forced to practise agriculture as the prevalence of the tsetse fly prevents their keeping cattle; therefore the culture in the fly-belts must necessarily differ from that of the neighbouring peoples who are free from the pest. Changes of season will also force an entire change in methods of living; and for this Mr. Sayce gives a table showing the seasonal change in the lives of the Arctic Eskimos. The author discusses dispassionately the problems involved in the study of material culture, including the question of diffusion and independent origin, and like most anthropologists he realises that both forces must be in operation. He does not claim "that the work contains any new or striking solutions of the problems, but an effort has been made to state simply and without prejudice what the problems are." In this aim he has amply succeeded, and his book is therefore worth reading and worth keeping.

M. A. MURRAY.

Sacraments of Simple Folk. By R. R. MARETT. [Pp. viii + 230.] (Oxford: Clarendon Press, 1933. 10s. net.)

THIS book, which comprises the Gifford Lectures of 1932–33, is written in Dr. Marett's usual inimitable style. His fundamental aim is to show how the sacramental features of ritual, those which invest a natural function with a supernatural authority, come to the aid of humanity in the most important spheres of activity. The sacrament of marriage thus deepens the import of the vital function of sexual union; the puberty rite of girls dedicates them to the supreme function of maternity; the clothing of a

ruler in spiritual dignity or even in divinity itself strengthens the respect for authority which is essential to social cohesion; the hocus-pocus of the medicine-man by comforting the mind tends also to facilitate the cure of the body. Even ritual obscenity and licence have a cathartic function.

Useful generalisations are happily expressed in novel ways. Thus the author says that totemism hardly amounts to a religion, being rather a cosmological extension of kinship—but the animal or plant which Man hails as his brother will find out sooner or later that it has to live up to the part! The whole treatment is stimulating, even to controversy; it is hardly to be expected then that the book will command general agreement on certain topics.

The author's conception of magic as a set of practices essentially anti-social, or of the term magician as implying something derogatory, and of magical processes as pseudo-mechanical, will assuredly provoke objection. And the dictum that magic can never become an instrument of law surely ignores its value as a socially approved penal force combating resistance to law or to initial malignant spells. Again, the moral element in primitive ritual appears to be over-stressed. It is difficult to credit the savage with really experiencing in his totemic performances a twinge of conscience at sacrificing animals to his hunger. To say that ceremonies of reincarnation "work morally by making him feel less of a beast of prey and more of a responsible man" is to inject into the data an atmosphere for which there is no recorded evidence.

But the originality of these and other opinions, provoking discussion, make the book a very useful contribution to the study of primitive religion in action.

RAYMOND FIRTH.

The Calendar and its Reform. By F. A. BLACK, T.D., F.R.S.E. [Pp vii + 80, with frontispiece and 2 other plates.] (London: Gall & Inglis, 1932. 2s. 6d net)

MR. BLACK begins with an historical account of the ancient Roman calendar, describing the systems traditionally associated with Romulus and Numa Pompilius, the reforms carried out by Julius Cæsar and the further changes introduced by Augustus. He explains how the months and days received their names, discusses the introduction of the new chronology by the Christians in the sixth century A.D. and describes the reforms effected by Pope Gregory. The Gregorian calendar has, he points out, harmonised the civil year with the solar year so well that it takes 3,323 years for the difference to amount to one day, though, as Herschel pointed out, even this difference could be avoided if the rule was extended so that years divisible by 4,000 were made years of 365 days. With this improvement, it would require the passage of 19,636 years before the difference amounted to one day. In recent times, however, a demand has arisen for another and a different amendment of the calendar so as to synchronise the week and the year. At present the week is an anachronism, forming no aliquot part of the year and deriving, in all probability, its number of days from the number of planets recognised in ancient times. Any reform proposed must be simple and likely to be accepted by all the various religious authorities. But the suggestion that the surplus day in common years and the two surplus days in leap years should be "non-counting days" involves, as the author shows, the continuous displacement of the days of the week as now known and is for that reason certain to meet with strenuous ecclesiastical opposition.

The following scheme is therefore suggested by the author: the common year to consist of 364 days (52 weeks) and the leap year of 371 days (53 weeks); every year that has the last two figures the same as each other and also the fifth year after it to be leap years, with the exception that years ending in '99 and also the 333rd year after each year that is exactly divisible by 400 shall be common years. A calendar is given constructed on these lines for the years 1939 to 2405: its greatest difference from the present calendar amounts to 7 days and this occurs only once. Moreover, the weekdays fall every year on the same day of the month; and Easter and other movable religious feasts can be fixed quite as readily and inconveniently as they are now, since the system proposed does not touch this question, and the ecclesiastical authorities can continue their calculations as before.

Mr. Black suggests, too, that the months be adjusted for the year of 364 days, so that each quarter of 91 days shall consist of two months of 28 days or four weeks and one of 35 days or five weeks, the extra week in leap years being intercalated between the end of June and the beginning of July and possibly called "Leap Week."

This is a serious proposal for settling a very troublesome question: in a less imperfect world it might possibly be adopted.

D. McKie.

Do You Speak Chimpanzee? By G. Schwidetzky. Translated from the German by Margaret Gardiner. [Pp. viii + 133.] (London: George Routledge & Sons, Ltd, 1932. 6s. net.)

Herr Schwidetzky's aim is to discover "through systematic investigation of the speech of animals (in particular apes, monkeys and prosimians), the first beginnings of speech and the languages of prehistoric and fossil men." He has chosen a difficult and unmapped territory, and his guides are geology, ethnology and Freudian psychology. Philology, he asserts, must no longer restrict itself to the study of speech that is exclusively human; for it thereby limits itself to the final developments of a natural phenomenon, evolved laboriously through the ages, and renounces all the early history of speech by adopting the defeatist attitude that it is concerned only with some mere few thousands of years out of a possible million. The application of Haeckel's recapitulation theory to the study of infant speech has, he says, produced, with the exception of a few valuable facts, only theoretical discussion: and, in any case, "the human child is born a finished manikin, equipped with human organs of speech" and therefore is incapable of yielding information on the ultimate origins of speech. The alternative is the study of the speech of monkeys and prosimians, and here the author considers that he has traced speech "in its essential outlines of sound and sense, far back to its early animal forms." He claims to have established that certain animals communicate intelligently with each other by means of sounds and, in that limited sense, speak, and that in these simple animal sounds are to be found the origins of human speech. This is at the very least a fairly strong statement, and the author hints that he expects to be called "arrogant," but he adds that he has spent fourteen years in observing mammals, especially monkeys and lemurs, in the zoological gardens of Europe and has studied "150 dictionaries of linguistic groups from all parts of the world." The present volume is more or less popular and gives only the preliminary data; a later and more scientific work will supply full details.

D. McKie.

Subject Index to Periodicals, 1932. [Pp. ix + 539.] (London : The Library Association, 1933. £3 10*s*.)

YEAR by year the Library Association continues its useful work of indexing the large body of material of a very miscellaneous kind to be found in the many journals which lie outside the net of scientific abstracting or indexing societies. In this way, Mr. Rowland Powel and his numerous voluntary contributors analyse each year the contents of some 600 periodicals and distribute them under the subject headings adopted by the Library of Congress, U.S.A. The usefulness of their work in thus dealing with nearly 26,000 entries is admitted, and full recognition should be given to the admirable way in which they carry out what must be a dull and laborious undertaking. It may, however, be argued with some justification that the Library Association is in danger of falling between two stools. By attempting to satisfy students of widely differing interests it runs the risk of being too superficial for all. In particular its list of foreign periodicals should be revised and extended. The present volume is as well printed and produced as its predecessors

J. W.

The Hollerith and Powers Tabulating Machines. By L. J. COMRIE, M.A., PH.D. [Pp. 48, with 41 figures.] (London : printed for private circulation, 1933. 2*s*.)

AMONG machines which have been developed during recent years, those manipulating punched cards are of importance in large-scale operations both in commerce (accounting) and in science (statistics). The processes involved fall into four groups : (1) the numerical coding of the material which it is desired to analyse ; (2) the punching (and verification) of the cards in accordance with the code numbers assigned ; (3) the sorting of the cards by reference to the holes punched in them , and (4) the tabulation of results. Two competing systems of machines for carrying out processes (2) to (4) are on the market, known respectively as the Hollerith and the Powers, the essential difference between them being that sorting is effected in the first by electrical, and in the second, by mechanical, means. This brochure contains a description of many of the machines used in the two systems, illustrated by numerous photographs and by diagrams showing how they work. Although most of the matter is general, some technical detail is included.

During the last few years improvements tending to greater accuracy and speed have been introduced, and the range of machines has been extended to provide for users whose needs are either more simple, or more complex, than the average. In addition to the two chief applications already mentioned, a third has been devised which is of great scientific interest—the numerical tabulation of mathematical functions. For this application Dr. Comrie is himself mainly responsible.

A. J. T.

BOOKS RECEIVED

(Publishers are requested to notify prices)

Mathematical Facts and Formulæ. By A. S. Percival, M.A., Trinity College, Cambridge. London and Glasgow: Blackie & Son, Ltd, 1933. (Pp. vi + 125, with 6 figures.) 4*s*. 6*d*. net.

Mathematical Tables. Vol. III: Minimum Decompositions into Fifth Powers. Prepared by L. E. Dickson, Professor of Mathematics in the University of Chicago, and published under the supervision of the British Association Committee for the Calculation of Mathematical Tables. London: Office of the British Association, 1933. 10*s*.

The Distribution of Prime Numbers. By A. E. Ingham, M.A., Fellow of King's College, Cambridge. Cambridge: at the University Press, 1932. (Pp. 114, with 4 figures.) 7*s*. 6*d*. net.

Continuous Groups of Transformations. By Luther Pfahler Eisenhart, Dod Professor of Mathematics in Princeton University. Princeton: Princeton University Press. London: Humphrey Milford, 1933. (Pp. x + 301.) 19*s*. 6*d*. net.

The Calculus of Finite Differences. By L. M. Milne-Thomson, M.A., F.R.S.E., Assistant Professor of Mathematics in the Royal Naval College, Greenwich. London: Macmillan & Co., Ltd, 1933. (Pp. xxiv + 558, with 23 figures.) 30*s*. net.

Inversive Geometry. By Frank Morley, M.A., Sc.D., Professor-Emeritus of the Johns Hopkins University, Research Associate of the Carnegie Institution, and F. V. Morley, D.Phil. London: G. Bell & Sons, Ltd., 1933. (Pp. xii + 273, with 67 figures.) 16*s*. net.

Analytic and Vector Mechanics. By Hiram W. Edwards, Ph.D., Associate Professor of Physics, University of California at Los Angeles. New York and London: McGraw-Hill Book Company, Inc., 1933. (Pp. x + 428, with 160 figures.) 24*s*. net.

The Gyroscopic Stabilization of Land Vehicles. By J. F. S. Ross, B.Sc., B.Sc.Eng., Ph.D., M.I.Mech.E., Assoc.M.Inst.C.E. London: Edward Arnold & Co., 1933. (Pp. viii + 172, with 42 figures.) 14*s*. net.

Symmetrical Components. As applied to the analysis of unbalanced electrical circuits. By C. F. Wagner, Research Engineer, Westinghouse Electric and Manufacturing Company, Member A.I.E.E., and R. D. Evans, Manager, Transmission Engineering, Westinghouse Electric & Manufacturing Company, Member A.I.E.E. With an introduction by C. L. Fortescue. New York and London: McGraw-Hill Book Company, Inc., 1933. (Pp. xvi + 438, with 218 figures.) 30*s*. net.

A Textbook of Physics. Vol. III: Electricity and Magnetism. By E. Grimsehl. Edited by R. Tomaschek, D.Phil., Professor of Physics, the University of Marburg. Authorised Translation from the 7th German Edition by L. A. Woodward, B.A. (Oxon), Ph.D. (Leipzig). London and Glasgow: Blackie & Son, Ltd, 1933. (Pp. xiv + 685, with 806 figures.) 25*s*. net.

Theoretical Physics. By W. Wilson, F.R.S, Hildred Carlile Professor of Physics in the University of London, Bedford College. Vol. II: Electromagnetism and Optics, Maxwell–Lorentz. London: Methuen & Co., Ltd., 1933. (Pp. xii + 316, with 78 figures.) 18*s*. net.

Electricity. By John Pilley. The Clarendon Science Series Oxford: at the Clarendon Press. London: Humphrey Milford, 1933. (Pp. xiv + 348, with 181 figures.) 7*s*. 6*d*. net.

Intermediate Magnetism and Electricity. By John E. Phillips, M.A., B.Sc., A.Inst.P., Wandsworth Technical Institute. London: Christophers, 1933. (Pp. xii + 365, with 270 figures.) 6*s*. 6*d*.

Mass-Spectra and Isotopes. By F. W. Aston, Sc.D., F.I.C., F.R.S., Nobel Laureate, Fellow of Trinity College, Cambridge. London: Edward Arnold & Co., 1933. (Pp. xii + 248, with 43 figures and 8 plates.) 15*s*. net.

The Theory of Atomic Collisions. By N. F. Mott, M.A., and H. S. W. Massey, Ph.D. International Series of Monographs on Physics. Oxford: at the Clarendon Press. London: Humphrey Milford, 1933. (Pp. xvi + 283, with 52 figures) 17*s*. 6*d*. net.

Direct and Alternating Currents. Theory and Machinery. By E. A. Loew, E.E., Professor of Electrical Engineering, University of Washington. New York and London: McGraw-Hill Book Company, Inc., 1933. (Pp. xv + 656, with 486 figures.) 27*s*. net.

Correction Tables for use with Platinum Resistance Thermometers. By G. S. Callendar and F. E. Hoare, Ph.D., A.R.C.S., D.I.C. London: Edward Arnold & Co., 1933. (Pp. 12.) 1*s*. net.

Modern Thermodynamics by the Methods of Willard Gibbs. By E. A. Guggenheim, M.A With a preface by F. G. Donnan, C.B.E., F.R.S. London: Methuen & Co., Ltd., 1933. (Pp. xvi + 206, with 10 figures.) 10*s*. 6*d*. net.

Physical Mechanics. An Intermediate Text for Students of the Physical Sciences. By Robert Bruce Lindsay, Ph.D., Associate Professor of Theoretical Physics in Brown University. London: Chapman & Hall, Ltd., 1933. (Pp. x + 436, with 162 figures.) 21*s*. net.

The Drama of Weather. By Sir Napier Shaw, Honorary Member and sometime President of the International Meteorological Committee. Cambridge: at the University Press, 1933. (Pp. xiv + 269, with frontispiece and 92 figures.) 7*s*. 6*d*. net.

Qualitative Chemical Analysis. Certain Principles and Methods used in Identifying Inorganic Substances together with a Systematic Survey of the Chemistry of these materials. By Roy K. McAlpine, Ph.D., and Byron A. Soule, Sc.D., University of Michigan. Based upon the text by A. B. Prescott and O. C. Johnson. London: Chapman & Hall, Ltd., 1933. (Pp. xii + 697, with 3 figures.) 21*s*. net.

Fluorescence Analysis in Ultra-Violet Light. By J. A. Radley, B.Sc., A.I.C., and Julius Grant, Ph.D., M.Sc., F.I.C. Being Vol. VII of a series of Monographs on Applied Chemistry, under the Editorship of E. Howard Tripp, Ph.D. London: Chapman & Hall, Ltd., 1933. (Pp. xii + 219, with frontispiece, 16 figures and 12 plates.) 15s. net.

A Textbook of Fire Assaying. By Edward E. Bugbee, Associate Professor of Mining Engineering and Metallurgy, Massachusetts Institute of Technology. Second edition. New York: John Wiley & Sons, Inc. London: Chapman & Hall, Ltd., 1933. (Pp. xii + 300, with 51 figures.) 18*s*. 6*d*. net.

Introduction to Physical Chemistry. By Alexander Findlay, Professor of Chemistry, University of Aberdeen. London: Longmans, Green & Co., 1933. (Pp. viii + 492, with 124 figures.) 7*s*. 6*d*. net.

An Introduction to Physical Chemistry. By F. B. Finter, M.A., late Scholar of Emmanuel College, Cambridge, Assistant Science Master at Clifton College. Revised edition. London: Longmans, Green & Co., 1933. (Pp. xvi + 276, with 4 plates and 48 figures.) 6*s*.

Recent Advances in Physical Chemistry. By Samuel Glasstone, Ph.D., D.Sc (Lond.), F.I.C., Lecturer in Physical Chemistry at the University of Sheffield. Second edition. London: J & A Churchill, 1933. (Pp. viii + 498, with 33 figures.) 15*s*. net.

An Introduction to Thermodynamics for Chemists By D. Johnston Martin, B Sc, A.I.C., Ph.D. London: Edward Arnold & Co., 1933. (Pp. viii + 344, with 41 figures.) 16*s*. net.

Inorganic Colloid Chemistry. By Harry Boyer Weiser, Professor of Chemistry at The Rice Institute. Vol. I: The Colloidal Elements. New York: John Wiley & Sons, Inc. London: Chapman & Hall, Ltd., 1933. (Pp. xii + 389, with 54 figures.) 28*s*. net.

Solvents. By Thos H. Durrans, D.Sc (Lond.), F.I.C., Director of the Research Laboratories of A. Boake, Roberts & Co., Ltd., London. Being Vol. IV of a series of Monographs on Applied Chemistry, under the Editorship of E. Howard Tripp, Ph.D. Third edition. London: Chapman & Hall, Ltd., 1933. (Pp. xviii + 206.) 10*s*. 6*d*. net.

A Short Organic Chemistry. By F. Sherwood Taylor, Ph.D., M.A., B.Sc., Assistant Lecturer, East London College. London: William Heinemann, Ltd., 1933. (Pp. viii + 378, with 43 figures.) 5*s*.

Organic Syntheses. An annual publication of satisfactory methods for the preparation of organic chemicals. Vol. XIII. W. H. Carothers, Editor-in-Chief. New York: John Wiley & Sons, Inc. London: Chapman & Hall, Ltd., 1933. (Pp. viii + 119.) 10*s* 6*d*. net.

Lehrbuch der organischen Chemie. By Dr. Paul Karrer, Professor an der Universität Zürich. Third edition. Leipzig: Georg Thieme, 1933. (Pp. xxiv + 922, with 4 figures and 2 plates.) RM.34—paper covers, RM.36—bound.

Organic and Bio-Chemistry. By R. H. A. Plimmer, D.Sc., Professor of Chemistry in the University of London, at St. Thomas's Hospital Medical School. Fifth edition. London: Longmans, Green & Co., 1933. (Pp. x + 624, with 69 figures and 1 plate.) 21*s*. net.

Annual Review of Biochemistry. Vol. II. Edited by James Murray Luck, Stanford University. Stanford, California: Stanford University Press. London: H. K. Lewis & Co., Ltd., 1933. (Pp. viii + 564.) 25*s*. net.

Indigenous Drugs of India. Their medical and economic aspects. By R. N. Chopra, M.A., M.D. (Cantab.), Lieut.-Colonel, Indian Medical Service, Professor of Pharmacology, School of Tropical Medicine and Hygiene, and Medical College, Calcutta. Calcutta: The Art Press, 1933. (Pp. xxii + 656.) Rs.15.

Maps and Survey. By Arthur R. Hinks, C.B.E., M.A., F.R.S. Third edition. Cambridge: at the University Press, 1933. (Pp. xii + 284, with 32 figures and 28 plates.) 12*s*. 6*d*. net.

Minerals and the Microscope. By H. G. Smith, A.R.C.S., B.Sc., F.G.S., Head of the Department of Geology, East London College. Third edition. London: Thomas Murby & Co. New York: D. van Nostrand Co., Inc., 1933. (Pp. xiv + 124, with frontispiece and 12 plates.) 5*s*. net.

History of the Theory of Ore Deposits. With a chapter on the Rise of Petrology. By Thomas Crook, F.G.S., Principal of the Mineral Resources Department, Imperial Institute, London. London: Thomas Murby & Co. New York: D. van Nostrand Co., Inc., 1933. (Pp. 163.) 10*s*. 6*d*. net.

On the Mineralogy of Sedimentary Rocks. A Series of Essays and a Bibliography. By P. G. H. Boswell, A.R.C.S., D.I.C., D.Sc., F.R.S., Sec.G.S., Professor of Geology in the Imperial College of Science and Technology and University of London. London: Thomas Murby & Co. New York: D. van Nostrand Co., Inc., 1933. (Pp. x + 393.) 21*s*. net.

Elements of Optical Mineralogy. An Introduction to Microscopic Petrography. By Alexander N. Winchell, Doct. Univ. Paris, Professor of Mineralogy and Petrology, University of Wisconsin. Third edition. Part II. Descriptions of Minerals. New York: John Wiley & Sons, Inc. London: Chapman & Hall, Ltd., 1933. (Pp. xviii + 460, with 362 figures.) 37*s*. 6*d*. net.

The Flora of Leicestershire and Rutland. A topographical, ecological and historical account, with biographies of former botanists (1620–1933). By Arthur Reginald Horwood, F.L.S. (formerly of Leicester Museum) and the late Charles William Francis Noel, 3rd Earl of Gainsborough. London: Oxford University Press, 1933. (Pp. ccxcviii + 688, illustrated with photographs and maps.) 35*s*. net.

The Study of Cacti. By Vera Higgins, M.A. With a Foreword by Sir William Lawrence, Bart., V.M.H. London: Blandford Press, Ltd., 1933. (Pp. 164, with 8 plates.) 7*s*. 6*d*. net.

British Economic Grasses. Their identification by the leaf anatomy. By Sydney Burr, M.Sc. (Leeds), Lecturer in Agricultural Botany, and Dorothy M. Turner, B.Sc. (Leeds), Univ. Dip. Hort. (Reading), Assistant Lecturer in Agricultural Botany, The University of Leeds. London: Edward Arnold & Co., 1933. (Pp. 94, with 34 plates and 2 text figures.) 10*s*. 6*d*. net.

Recent Advances in Plant Physiology. By E. C. Barton-Wright, M.Sc. (Lond.), F.R.S.E., Chief Assistant at the Scottish Society for Research in Plant Breeding, Corstorphine, Edinburgh. Second edition. London: J. & A. Churchill, 1933. (Pp. x + 342, with 54 figures.) 12*s*. 6*d*. net.

Recent Advances in the Study of Plant Viruses. By Kenneth M. Smith, D.Sc., Ph.D., Potato Virus Research Station, School of Agriculture, University of Cambridge. With Foreword by F. T. Brooks, M.A. F.R.S., Reader in Mycology, University of Cambridge. London: J. & A. Churchill, 1933. (Pp. xii + 423, with 67 figures and 1 plate.) 15*s*. net.

Index Kewensis Plantarum Phanerogamarum. Supplement VIII (1926–1930). By A. W. Hill Compiled at the Herbarium of the Royal Botanic Gardens, Kew. Oxford: at the Clarendon Press. London: Humphrey Milford, 1933. (Pp. iv + 256) £3 15*s*. net.

Bio-Electric Potentials. By The Rev. M. C Potter, Sc D., M.A., Emeritus Professor of Botany in the University of Durham Cambridge: W. Heffer & Sons, Ltd., 1933. (Pp. 43.) 1*s* net

Plant Parasitic Nematodes and the diseases they cause. By T. Goodey, D Sc, Principal Research Assistant, Institute of Agricultural Parasitology, London School of Hygiene and Tropical Medicine With a Foreword by R T. Leiper, M.D., D.Sc., F R.S, Professor of Helminthology in the University of London, and Director of the Institute of Agricultural Parasitology. London: Methuen & Co., Ltd., 1933. (Pp. xx + 306, with 136 figures.) 21*s*. net.

Biology in Education. A Handbook based on the Proceedings of the National Conference on the Place of Biology in Education, organised by the British Social Hygiene Council. Edited and with Introductions by J. G Crowther. London: William Heinemann, Ltd., 1933. (Pp. x + 204 and appendix.) 7*s* 6*d*. net.

Laboratory Directions in General Zoology. By Winterton C. Curtis, Professor of Zoology, Mary J. Guthrie, Associate Professor of Zoology, Farris H. Woods, Assistant Professor of Zoology, University of Missouri. Second edition, revised. New York: John Wiley & Sons, Inc. London: Chapman & Hall, Ltd., 1933. (Pp. xxxii + 164, with 60 figures.) 9*s*. 6*d*. net.

Zoology. The Invertebrata, Part I. By Robert A. Staig, M.A., PhD., F.R.S.E., Lecturer in Zoology, University of Glasgow. Third edition. The Catechism Series. Edinburgh: E. & S Livingstone, 1933. (Pp. 88, with 16 figures.) 1*s*. 6*d*. net.

Animal Biology. By Robert H. Wolcott, Professor of Zoology, University of Nebraska. New York and London: McGraw-Hill Book Company, Inc., 1933. (Pp. xviii + 615, with 335 figures.) 21*s*. net.

The Biology of the Protozoa. By Gary N. Calkins, Ph.D., Sc.D., Professor of Protozoology, Columbia University. Second edition. London: Baillière, Tindall & Cox, 1933. (Pp. xii + 607, with 2 plates and 223 figures.) 37*s*. 6*d*. net.

British Beetles. Their Homes and Habits. Including chapters on how to identify, collect and study. By Norman H. Joy, M.R.C.S., L.R.C.P.,

F.R.E.S., M.B.O.U. London and New York: Frederick Warne & Co., Ltd., 1933. (Pp. xii + 143, with 31 plates and 21 figures in the text.) 5*s*. net.

Functional Affinities of Man, Monkeys, and Apes. A study of the bearings of physiology and behaviour on the taxonomy and phylogeny of lemurs, monkeys, apes, and man. By S. Zuckerman, M.A., D.Sc., M.R.C.S., Research Associate, Yale University, lately Anatomist to the Zoological Society of London and Demonstrator of Anatomy, University College, London. London: Kegan Paul, Trench, Trubner & Co., Ltd., 1933. (Pp. xviii + 203, with 24 plates and 4 figures.) 10*s*. 6*d*. net.

Nature and Nurture. By Lancelot Hogben, M.A., D.Sc., Professor of Social Biology in the University of London. Being the William Withering Memorial Lectures on "The Methods of Clinical Genetics" delivered in the Faculty of Medicine of the University of Birmingham for the year 1933. London: Williams & Norgate, Ltd., 1933. (Pp. 144, with 2 figures and 21 tables.) 6*s*. 6*d* net.

The General Theory of Evolution. By Malcolm MacTaggart. Cambridge: W. Heffer & Sons, Ltd, 1933. (Pp. vi + 50.) 1*s* 6*d*. net.

Handbook of Physiology. By the late W. D. Halliburton, M.D., LL.D., F.R.C.P., F.R.S., and R. J. S. McDowall, M.B., D.Sc., F.R.C.P. (Edin.), Professor of Physiology, University of London, King's College. Thirty-third edition. London: John Murray, 1933. (Pp. xii + 971, with 382 figures and 4 plates) 18*s* net.

Human Embryology and Morphology By Sir Arthur Keith, M.D., F.R.S., LL.D., D.Sc., F R C S. (Eng.), Master of the Buckston Browne Research Farm, formerly Conservator of the Museum and Hunterian Professor, Royal College of Surgeons of England. Fifth edition. London: Edward Arnold & Co., 1933. (Pp. viii + 558, with 535 figures.) 32*s*. 6*d*. net.

Mental Diseases. Second edition. The Catechism Series. Edinburgh: E. & S. Livingstone, 1933. (Pp. 80.) 1*s*. 6*d*. net.

Mental Defect. By Lionel S. Penrose, M.A., M.D., Research Medical Officer, Royal Eastern Counties Institution, Colchester. London: Sidgwick & Jackson, Ltd., 1933. (Pp. xii + 184, with 5 plates and 2 figures.) 8*s*. 6*d*. net.

Heredity and the Social Problem Group. By E. J. Lidbetter. Vol. I. London: Edward Arnold & Co., 1933. (Pp. 160, with 26 diagrams.) 21*s*. net.

An Outline of Immunity. By W. W. C. Topley, M.A., M.D., F.R.C.P., F.R.S., Professor of Bacteriology and Immunology in the University of London. London: Edward Arnold & Co., 1933. (Pp. viii + 416, with 37 diagrams and charts.) 18*s*. net.

Maternal Mortality and Morbidity. A Study of their Problems. By J. M. Munro Kerr, M.D., F.R.F.P.S. (Glas.), F.C.O.G., Regius Professor of Midwifery, University of Glasgow, Obstetric Surgeon, Glasgow Royal Maternity and Women's Hospital. Edinburgh: E. & S. Livingstone, 1933. (Pp. xviii + 382, illustrated with maps, diagrams, charts, skiagrams and hospital plans.) 25*s*. net.

Tuberculosis. Its Cure and Prevention. By Gordon Tippett, M.B. London: Methuen & Co., Ltd., 1933. (Pp. xii + 242, with frontispiece.) 7*s*. 6*d*. net.

Charles Darwin's Diary of the Voyage of H.M.S. "Beagle" Edited from the MS. by Nora Barlow. Cambridge: at the University Press, 1933. (Pp. xxx + 451, with 3 illustrations and 2 maps.) 21*s*. net.

Nansen of Norway. By Charles Turley. London. Methuen & Co., Ltd., 1933. (Pp. 210, with 4 plates and 2 maps.) 5*s*. net.

The Physician's Art. An attempt to expand John Locke's fragment "De Arte Medica" By Alexander George Gibson. Oxford: at the Clarendon Press. London: Humphrey Milford, 1933. (Pp. 237.) 7*s*. 6*d*. net.

Thomas Young, F.R.S. Philosopher and Physician. By Frank Oldham, M.A., B Sc., A Inst.P., formerly scholar of St. John's College, Cambridge. London. Edward Arnold & Co., 1933. (Pp. 159, with 14 figures and 2 plates.) 6*s* net.

The Heroic Age of Science. The Conception, Ideals, and Methods of Science among the Ancient Greeks. By William Arthur Heidel, Research Professor of the Greek Language and Literature in Wesleyan University, Research Associate of the American Council of Learned Societies and of the Carnegie Institution of Washington. Baltimore: The Williams & Wilkins Company, for the Carnegie Institution of Washington, 1933. London: Baillière, Tindall & Cox. (Pp. viii + 204.) 12*s*. 6*d*. net.

Limitations of Science. By J. W. N. Sullivan. London: Chatto & Windus, 1933. (Pp. vi + 304.) 7*s*. 6*d*. net.

God and the Astronomers. Containing the Warburton Lectures 1931–33. By William Ralph Inge, K.C V.O., D.D., F.B.A, Dean of St. Paul's. London: Longmans, Green & Co., 1933. (Pp. xiv + 308.) 12*s*. 6*d*. net.

Science and God. By Bernhard Bavink. Translated by H. Stafford Hatfield. London: G. Bell & Sons, Ltd., 1933. (Pp. x + 174.) 5*s*. net.

The Universe and Life. By H. S. Jennings, Henry Walters Professor of Zoology and Director of the Zoological Laboratory, The Johns Hopkins University. New Haven: Yale University Press. London: Humphrey Milford, 1933. (Pp. 94.) 7*s*. 6*d*. net.

The Origin of Living Matter. By Dr. H. A. Gray and N. M. Bligh. Cambridge: W. Heffer & Sons, Ltd., 1933. (Pp. 26, with 1 table.) 1*s*. 6*d*. net.

The Progress of Man. A short survey of his evolution, his customs and his works. By A. M. Hocart, late Archæological Commissioner, Ceylon. London: Methuen & Co., Ltd., 1933. (Pp. xvi + 316.) 7*s*. 6*d*. net.

Our Forefathers. The Gothonic Nations. A Manual of the Ethnography of the Gothic, German, Dutch, Anglo-Saxon, Frisian and Scandinavian Peoples. By Gudmund Schutte, Ph.D. Vol. II. Cambridge: at the University Press, 1933. (Pp. xvi + 482, with 20 figures.) 30*s*. net.

The Long Road. From Savagery to Civilisation. By Fay-Cooper Cole, Professor and Chairman, Department of Anthropology, University of Chicago. A Century of Progress Series. Baltimore: The Williams &

Wilkins Company in co-operation with the Century of Progress Exposition, 1933. London: Baillière, Tindall & Cox. (Pp. xii + 100, with 6 figures.) 5*s*. net.

Differenzierungserscheinungen in einigen afrikanischen Gruppen. Ein Beitrag zur Frage der primitiven Individualität. By Dr. Sjoerd Hofstra. Amsterdam: Scheltema & Holkema's Boekhandel N.V., 1933. (Pp. viii + 214.)

The Diffusion of Culture. By G. Elliot Smith, M.A., M.D., Litt.D., D.Sc., Ch.M., F.R.C.P., F.R.S. London: Watts & Co., 1933. (Pp. x + 244, with 19 figures.) 7*s*. 6*d*. net.

Sexual Regulations and Human Behaviour. By J. D. Unwin, M.C., Ph.D. (Cantab.). London: Williams & Norgate, Ltd., 1933. (Pp. xvi + 108.) 7*s*. 6*d*. net.

The Human Personality. By Louis Berg, M.D. London: Williams & Norgate, Ltd., 1933. (Pp. xvi + 322.) 8*s*. 6*d*. net.

Consciousness: Brain-Child By Percy A. Campbell. East Cleveland, Ohio, 1933. (Pp. viii + 109.) $1.50.

The Method and Theory of Ethnology. An Essay in Criticism. By Paul Radin. New York and London: McGraw-Hill Book Company, Inc., 1933. (Pp. xvi + 278.) 15*s*. net.

The Principles of Logic. An introductory survey. By C. A. Mace, M.A., Reader in Psychology in the University of London. London and New York: Longmans, Green & Co., 1933. (Pp. xiv + 388.) 12*s*. 6*d*. net.

Psychical Research. The Science of the Super-normal. By Hans Driesch, Professor of Philosophy in the University of Leipzig. Authorised translation by Theodore Besterman, Investigation Officer of the Society for Psychical Research. London: G. Bell & Sons, Ltd., 1933. (Pp. xvi + 176.) 5*s*. net.

Genealogy of Love. By Curt Thesing, M.D. Translated by Eden and Cedar Paul. London: George Routledge & Sons, Ltd., 1933. (Pp. x + 283, with 73 figures.) 15*s*. net.

Riddles of the Gobi Desert. By Sven Hedin. London: George Routledge & Sons, Ltd., 1933. (Pp. x + 382, with 24 plates and a map.) 18*s*. net.

Anonymous Letters. A Study in Crime and Handwriting. By Robert Saudek, Ph.D. London: Methuen & Co., Ltd., 1933. (Pp. viii + 142, with 8 plates and 10 figures.) 5*s*. net.

The Subject Index to Periodicals, 1932. London: The Library Association, 1933. (Pp. ix + 539.) £3 10*s*.

The Hollerith and Powers Tabulating Machines. By L. J. Comrie, M.A., Ph.D., Superintendent, H.M. Nautical Almanac Office. London: Printed for private circulation, 1933. (Pp. 48, with 41 figures.) 2*s*.

The Sound Motion Picture in Science Teaching. By Phillip Justin Rulon, Graduate School of Education, Harvard University. Cambridge, Massachusetts. Harvard University Press. London: Humphrey Milford, 1933. (Pp. xvi + 236.) 11*s*. 6*d*. net.

PLATE I

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SCIENCE PROGRESS

THE NORTHERN LIGHTS AND THE STORY THEY TELL

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The Northern Lights or Auroræ Polares are luminous phenomena particularly frequent in the polar regions. They illuminate the polar night during the winter, and give, as it were, a compensation for the absence of sunlight. Their most striking features are their irregular and sudden appearance, the great variety of their forms and colours, and their peculiar and rapid motions.

Descriptions of the auroral phenomena and views regarding their origin date back to the times of the Greeks and Romans. During the Middle Ages, when the human mind was bent towards mysticism and astrology, it was only too natural that auroral displays—especially in those regions where they are rare—were regarded as instruments in the hands of divine powers to give warnings to an evil world and to foretell coming events.

A systematic study of the auroral phenomena on a sound scientific basis began just about 200 years ago, when in 1733 De Mairan published his treatise entirely devoted to the Auroræ Polares. From the time of Mairan to the present day an enormous amount of skill and labour has been devoted to auroral studies, in order to find out the laws governing the phenomena and to explain their origin.

In the nineteenth century the activity of eminent investigators and a number of polar expeditions gave us a great many valuable data, by means of which a number of most important empirical laws and relationships were established; but until the end of that century all attempts to develop a satisfactory theory were more or less failures, although many of them contained traces of truth.

The reason for this failure is obvious. The auroral theories

had to be based on physical knowledge, and a sound auroral theory could not be developed until physical science had made known to us those processes which are concerned in the production of auroræ and magnetic disturbances.

The new epoch in the auroral investigations was inaugurated in 1896 by the theory of Birkeland, according to which auroræ and certain common types of magnetic disturbances are due to electric rays emitted from the sun. Birkeland's theory as well as his own extensive work and original treatment of the problems have, directly and indirectly, inspired all the more important auroral studies ever since. A brilliant account of the state of our knowledge about the auroræ before this time is given by A. Angot in his book *The Aurora Borealis*, published in 1896, just the very year when Birkeland announced his new theory.

In the present article we shall devote our attention mainly to the results obtained during the last epoch, which practically means results obtained during this century. For the sake of completeness it will be necessary to include also a number of facts and relationships resulting from earlier investigations.

Auroral investigations can be followed up in two directions In the one we try to trace the origin of the auroral displays and to follow the phenomenon from its manifestation on the earth to its origin on the sun. These studies will no doubt give us information about such solar processes as may result in the emission of electric rays. Secondly we know that the auroral luminescence, being a fairly local phenomenon, must be attached to our atmosphere, and to that part of it which forms its limiting aspect towards empty space. In other words the auroræ perform an experiment on a large scale in the upper atmosphere, and so give us a means —and in fact the best we have got—for the study of the composition and physical state of the extreme upper layers of our atmosphere.

Auroral Forms

The northern lights may appear as a luminous fog or haze covering large parts of the sky (Plate II, Fig. 1), or as bright areas with fairly sharp boundaries, where the light intensity undergoes periodic changes with periods of some seconds (pulsating areas), and such areas may sometimes be scattered all over the sky. Very often the auroræ take the shape of a regular arc stretched across the sky usually in a fairly definite direction and with a sharp lower limit, below which the sky from contrast appears quite dark (the dark segment). When such an arc passes near the zenith it takes the form of a luminous belt with fairly sharp

limits (Plate II, Fig. 2), in certain cases the band is split up into parallel layers (Plate II, Fig. 3). Sometimes such split bands are pulsating.

The arcs may gradually develop into a thinner band with radiant structure, which becomes more uneasy and begins to move. It appears as if the arc was composed of vertical streamers added one to another so as to form a long thin band stretched across the sky (Drapery-shaped arc, Plate II, Fig. 4)

The streamers may vary in length and change in intensity. The intensity variations may move fairly regularly and rapidly along the band, like waves of light. The band may begin to change form and position and break up into short thin strips with pronounced radiant structure—like *draperies* or curtains hanging from the sky (Plate II, Fig 5).

The ray-bundles need not add up to form a coherent drapery or band, but may appear with irregular distribution or as one or a few isolated rays. As the ray structure becomes more pronounced the ray streamers become longer, and as a rule, the isolated rays are the longest. When a large number of ray-bundles and draperies appears near the zenith, it seems, on account of the perspective effect, as if rays were shooting out from a definite point (the radiant point) on the sky, and we have the most brilliant of all forms, the corona (Plate II, Fig. 6).

Geographical Distribution

When we pass from the equatorial region, where no auroræ appear, towards the polar regions, the auroral frequency increases. This increase, however, does not go on until we reach the poles, but there is a zone of maximum auroral frequency round each pole. The distribution of auroral frequency is roughly given by the well-known map worked out by Fritz in 1869. His lines of equal frequency (isochasms) form a series of nearly parallel circular curves. These circles do not have their centre at the pole, but at a point which, on the northern hemisphere, has a polar distance of about 10° and longitude 75° W Later investigations have shown that this "auroral pole" coincides with the point where the magnetic axis of the earth strikes the earth's surface (magnetic axis point).

Up to the present time the work of Fritz forms our only source of knowledge regarding the distribution of auroral frequency. The results are based on very unsatisfactory material, and a revision of the auroral frequency map will be an important task in future auroral work.

In order to determine in a satisfactory way the geographical distribution of auroral frequency, we should have systematic observations from a number of localities, distributed all over the world, and especially in the polar regions, and we should want series of observations covering long periods. It is an enterprise which would naturally present itself for international co-operation, and one which, on account of the great interest attached to these phenomena, ought to be organised as soon as possible.

The Direction of the Bands and Streamers.

The arcs and bands have a very marked tendency to take up a definite direction, which may be characterised by the azimuth of the end directed to the west. It appears that the average azimuth is different at different localities, and the variations are particularly large in the polar region. At lower latitudes where the variation of the average azimuth is not very pronounced, it was found that very often the bands had a tendency to be perpendicular to the magnetic meridian.

A more systematic investigation on the direction of arcs and bands for polar stations based on the material for the polar year 1882–83 showed that this rule did not apply at all to polar stations. The direction of the arcs stood in no simple relation to the magnetic meridian, but was found to be related to the great circle through the magnetic axis point. The writer introduced magnetic co-ordinates (*e.g.* magnetic azimuth and hour angle) referred to the magnetic axis point as pole, and showed that the magnetic azimuth of the arcs were nearly equal for most polar stations including those situated near the point commonly called the magnetic pole. The magnetic azimuth was found to be about 100°. The fact that the magnetic azimuth is larger than 90° has an important bearing on the question regarding the sign of the charge carried by the electric rays from the sun

The direction of the ray streamers is most accurately determined by the position of the radiant point. It is found that this direction nearly coincides with the direction of the magnetic lines of force as they are observed on the surface of the earth. In other words that the radiant point coincides with magnetic zenith—the point where the lines of force cut the celestial sphere.

In individual cases we find that the radiant point does not coincide exactly with magnetic zenith, but shows deviations of a few degrees. These deviations have been shown to exist when the radiant point is measured from auroral photographs, and are no doubt real. The writer has made a systematic study of these

deviations. He finds that the average position lies below the magnetic zenith and gives the following interpretation. The radiant point will at any moment give the direction of the lines of force as it actually exists in the auroral region. The change of direction is due to perturbing fields which may have in those regions a much larger influence on the direction of the magnetic lines of force than they have near the ground The lowering of the radiation point means that, on an average, the perturbing influences have a tendency to act in one direction

Aurora and Magnetic Disturbances.

Halley in 1716 observed that auroræ are accompanied by magnetic disturbances. This correlation has been studied by a great many authorities, but no very simple connection is found which can be applied to individual cases Very often we find that the most intensive auroræ occur at the time when the magnetic storm measured in the same locality has its maximum intensity. Comparing auroral observations from Bossekop with magnetic records from the Haldde Observatory (13 km apart) the writer found cases when strong auroræ appeared without being accompanied by marked perturbing forces This result shows that the "polar magnetic storms" particularly studied by Birkeland, are not directly affected by the electric rays which penetrate into the atmosphere and produce auroræ, but mainly by electric radiations which are turned back into space at somewhat higher levels. This means that only a small fraction of the electric rays producing the polar magnetic storms shoots down so far as to produce luminescence in the form of northern lights

Connection between Auroræ and the Sun

For good reasons the observation of the auroræ is restricted to the time of day when the sun is below the horizon, and the fact that the auroræ may appear at any hour of the night would naturally convey the idea that the relation between the sun and the auroræ is an indirect one. It is found, however, that the auroral frequency shows a pronounced diurnal variation, which establishes some connection between auroræ and solar action. In lower latitudes we find a pronounced maximum between 9 and 10 o'clock in the evening. This would indicate that when the earth rotates, the diurnal maximum, at any rate for each latitude, should have a fixed position relative to the sun.

From a statistical study of the material from the first polar year, the writer found that this rule was far from true for the

polar regions. For stations near the auroral zone the local hour of the maximum differed by as much as four hours. Introducing local magnetic time, however, it was found that the principal maximum appeared at about the same local magnetic time for all the polar stations considered In fact, the maximum appeared just about one hour before *magnetic midnight*. This shows that the magnetic axis essentially determines not only the geographical, but also the diurnal distribution of auroral frequency, and it indicates that the connection between the auroræ and the sun is a fairly direct one, while the magnetic field plays a fundamental part in the distribution of the agency which produces the auroræ

From studies of the diurnal distribution of "polar storminess" Birkeland finds that the type of variation makes it necessary to assume a very direct connection between the sun and the polar magnetic storms

It is well known that auroræ and magnetic disturbances have a tendency to re-occur after twenty-seven days. This apparent monthly period is connected with the revolution of the sun and is due to the fact that the source of electric rays in some way associated with the sunspot activity may last during several revolutions.

The auroral frequency shows an annual variation, but this depends essentially on the latitude Stations on lower latitudes

EXPLANATION TO PLATE II

FIG. 1—Quiet broad auroral arc across the zenith, photographed by Vegard, January 1913.

FIG. 2.—Quiet arc photographed by Vegard at Tromsö, March 1923.

FIG. 3.—Split pulsating arc photographed by Krogness at the Haldde Observatory, March 2, 1914

FIG. 4.—Drapery-shaped arc photographed by Vegard at Tromsö, March 25, 1923.

FIG. 5.—Drapery photographed by Krogness at Haldde, November 26, 1914.

FIG. 6.—Corona photographed by Krogness near Haldde, November 26, 1914.

FIGS. 7, 8, 9, 10.—SPECTRA OBTAINED BY VEGARD AND HIS COLLABORATORS

FIG. 7.—Spectrum on pan-chromatic plate obtained with small spectrograph at the New Auroral Observatory 1933.

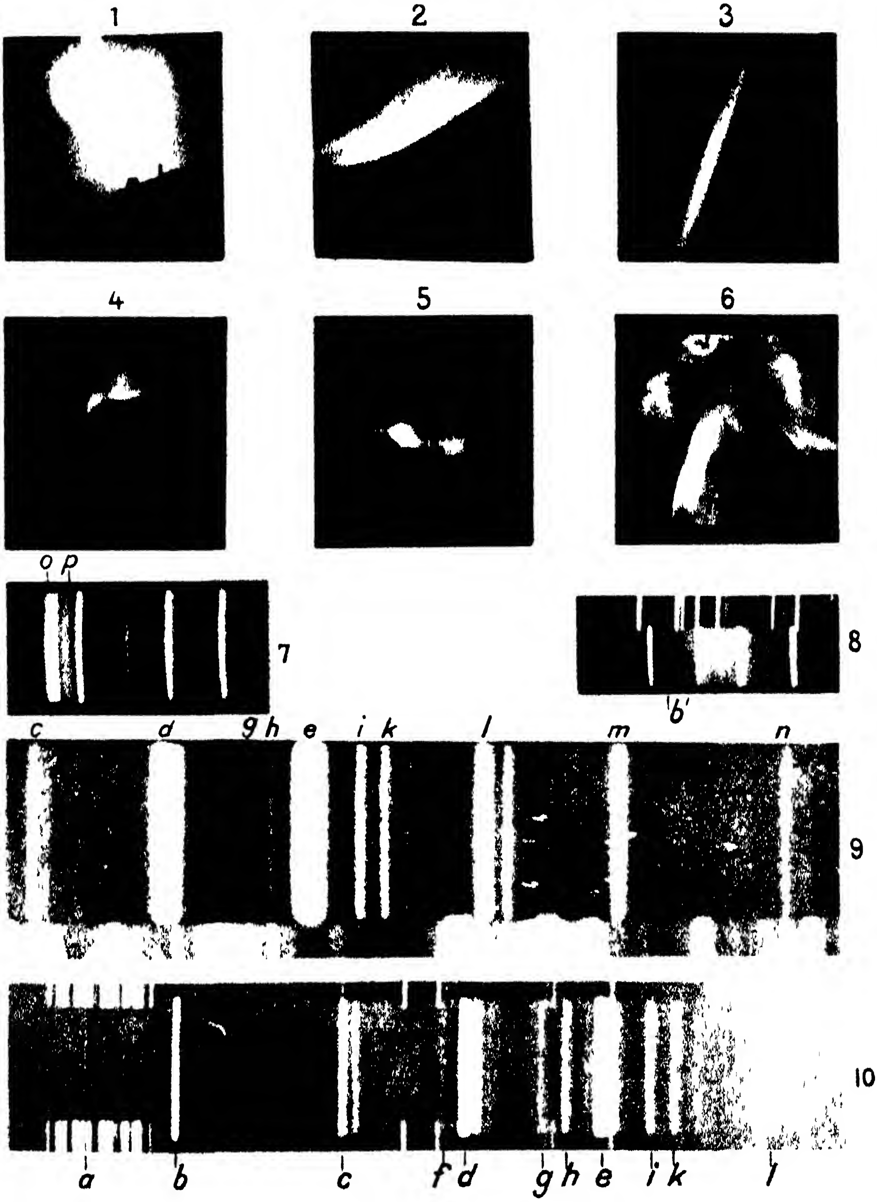
FIG. 8.—Spectrogram obtained December 1926 on plate sensitised with pinaflavol showing second green line b′.

FIG. 9.—Spectrogram of the ultra-violet region obtained with large quartz spectrograph, November 1922, at Tromsö.

FIG. 10.—Spectrogram obtained with panchromatic plate with large spectrograph (Plate III, Fig. 2) at the Auroral Observatory, Tromsö, 1931–2.

a indicates red line $\lambda = 6300$
b „ strong green line $\lambda = 5577$
b′ „ second „ „ $\lambda = 5239$

c, d, e, the strongest bands of the negative group of nitrogen
f, g, h, i, k, l, m, n, strongest bands of second positive group of nitrogen
o, p, bands in red of the first positive group of nitrogen.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give two maxima, one in the spring and one in the autumn, with a minimum in January; stations near the auroral zone show a maximum in midwinter. The writer explains this difference by assuming that the auroræ are carried towards lower latitudes through the effect of magnetic disturbances. The maxima in the spring and autumn are then merely an effect of the simultaneous maxima of magnetic storminess.

Perhaps the most interesting connection between sun and auroræ consists in the correlation between auroral frequency and sunspot numbers. The idea of a close relation between auroræ and sunspots occurred to Mairan, but was shown definitely by the work of R Wolf, Secchi, Hansteen, Fritz, Loomis and Lovering. The maximum of auroral frequency occurring at the time of sunspot maximum is not so pronounced near the auroral zone as at lower latitudes. In fact, Tromholt finds no pronounced maximum for stations near the auroral zone. The writer thinks this is partly due to the fact that in the determination of auroral frequency no attention is paid to the intensity Secondly, the fact that the eleven-year sunspot cycle is more pronounced for auroræ at lower latitudes is explained by assuming, as before, that the auroræ are driven towards lower latitudes through the effect of magnetic disturbances. The transfer of auroræ towards lower latitudes will reduce the frequency near the ordinary auroral zone, and thus explain why the maximum here is less pronounced.

From what is said it will evidently be of great importance to show more directly that the auroræ are driven towards lower latitudes by the effect of perturbing magnetic fields.

On the suggestion of the writer Mr. A. Röstad undertook the laborious work of comparing the position of auroral displays observed in Trondheim, Oslo and Holland with the strength of the simultaneous magnetic storms at Potsdam. He was able to prove the existence of a close correlation between the strength of the magnetic perturbation and the position of the auroræ, and it was found that the distance the auroræ were carried from the auroral zone towards lower latitudes increased in a definite way with the intensity of the magnetic disturbance. The rule does not only hold statistically, but it applies to individual cases.

The Auroral Theory

Three years before Birkeland published his first papers regarding his auroral theory, the Danish meteorologist A. Paulsen had proposed a hypothesis in which cathode rays played a certain part. He assumed cathode rays to be formed in the earth's atmosphere

by ultra-violet rays from the sun, and that these cathode rays found their way to the poles where they produced auroral displays. This hypothesis, however, cannot be upheld, because it fails to explain well-established facts relating to the auroræ.

It cannot explain the abrupt and irregular occurrence of auroræ, and in order to understand their connection with sunspot frequency, we should have to introduce some additional hypothesis. When the whole surface of the earth forms the source of cathode rays, we cannot explain the formation of thin bands and arcs, and we cannot account for the fact that auroræ and polar magnetic storms have a pronounced maximum near magnetic midnight. The hypothesis of Paulsen is also unable to account for the fact that the curves of equal auroral frequency have their centres at the magnetic axis point and that the diurnal variation follows local magnetic time. In spite of these difficulties, partly pointed out by Birkeland, the hypothesis of Paulsen has been supported in later years by eminent scientists, *e g* by Villard, Hulburt and Maris.

Birkeland on the other hand assumes that the auroræ and most magnetic disturbances are produced by *fairly narrow bundles of electric rays emitted from fairly limited active areas on the sun* which are in some way connected with the process responsible for the formation of sunspots. The hypothesis of Birkeland thus explains the close connection between auroral and sunspot frequency and the abrupt and irregular occurrence of auroræ and magnetic disturbances.

Some years after Birkeland announced his theory, E. W. Maunder published the results of most important investigations on the occurrence of magnetic storms, in which he showed that great magnetic storms usually appeared when sunspot groups were observed near the central meridian of the sun. These results give further evidence of the existence of those narrow ray bundles which formed a fundamental part of Birkeland's theory.

Birkeland performed a number of experiments in order to study the orbits of electric rays in a magnetic field and to find the consequences of his hypothesis. He was able to show that when a magnetised sphere was exposed to a stream of cathode rays, the latter could only strike the sphere in zones round the magnetic axis point. Under certain conditions the rays were seen to strike the sphere along a spiral, which turned round the magnetic axis point. He thus showed that the auroral zone followed from his hypothesis as a result of the deviation of the electric rays in the magnetic field of the earth. He also showed that the rays could come directly down on the night side of the earth, and although

we cannot either experimentally nor mathematically determine exactly the diurnal distribution, the theory of Birkeland allows us to understand that auroræ and polar magnetic storms produced by electric rays from the sun may have pronounced maxima near magnetic midnight, and that the diurnal distribution follows magnetic time

From the theory of Birkeland we can also understand the existence of rapid motions and intensity variations, when the fluctuations in the intensity of the ray bundle and the influence of perturbing fields are taken into account. The simplicity of Birkeland's theory is shown by the fact that some of the more important consequences can be derived mathematically.

These mathematical problems which Birkeland's theory suggests, have been subject to extensive and profound analysis by C. Störmer.

He has first of all treated the problem of determining the orbit of an electric ray in the field of an elementary magnet, and discussed the result with special reference to the auroral phenomena.

The results of Störmer's mathematical calculations are in good agreement with Birkeland's experiments, and they have recently been confirmed in a most striking way by some beautiful experiments carried out by Brüche at the A.E.G. research laboratory in Berlin. Störmer has been able to show mathematically that the auroral zone is a simple consequence of the basic hypothesis of Birkeland, and he can show that under certain conditions the electric rays will be drawn out laterally to form narrow auroral bands.

The conditions which the mathematical theory requires are, however, usually not present when bands and draperies actually occur, and the writer has proposed a theory of auroral arcs and curtains which differs from that of Störmer. In order to explain the formation of long arcs, he supposes the electric rays to be deviated by current systems situated at distances small compared with that of the sun, but large compared with the radius of the earth. The formation of draperies, he explains by assuming that the bundles of electric rays are not homogenous, but composed by mixtures of different carriers.

The Position in Space of the Auroræ

As a rule quiet auroræ have not very sharp boundaries, and if their outlines are sharp, they are usually changing position and moving rapidly. Consequently an accurate determination of the position of an auroral display was very difficult, until the develop-

ment of the photographic technique made it possible to fix the auroral forms on the photographic plate. It is therefore quite remarkable that even the earliest measurements made at lower latitudes placed the auroræ in the right height interval between one hundred and several hundred kilometres.

The measurements by visual methods, carried out in the polar regions, however, seem to be much more uncertain—probably because they were made for rapidly moving auroræ.

Thus a number of eminent authorities find auroræ reaching to within a few hundred metres from the ground, but these results are probably wrong, and they are not supported by the photogrammetric measurements. Extensive series of height measurements have now been made by means of the photographic method devised by Störmer. In this method an aurora is photographed simultaneously from two stations, and the position in space of any peculiar feature of the aurora is found from the different positions of the pictures relative to the stars. A convenient camera of high light power allowing six pictures to be taken on the same plate was constructed by Störmer and Krogness (Plate III, Fig. 1).

In the region near the auroral zone measurements were made in 1910 and 1913 by Störmer at Bossekop, and in 1912–14 by Vegard and Krogness at Haldde, and by Harang and Tönsberg at the new Auroral Observatory at Tromsö (Plate I). The results obtained by the different observers are in good agreement, and may be briefly summarised as follows.

The average height of the lower limit is about 106 km. for quiet forms, but is somewhat larger for auroræ with pronounced radiant structure and largest for isolated rays for which the average height of the lower limit is about 120 km.

The difference between the various forms is greater when we consider the upper limit. For arcs it is about 150 km., for draperies 175 km., and for rays 250 km.

The altitudes fluctuate largely in individual cases.

Near the auroral zone the lower limit has been found to vary between say 150 km. and 70 km. The lowest value was measured by Harang and Bauer at the Auroral Observatory, Tromsö, from an auroral arc with an intensive red colour near the bottom edge. In the auroral region no auroral ray has been found reaching altitudes higher than 300 km.

Störmer's measurements at lower latitudes (near Oslo) have shown that the lower limit does not vary essentially with latitude, but a very marked difference is found for the upper limits of the rays. These he often finds may reach values of 500–800 km., and

lately he found that the rays may reach particularly large altitudes early in the evening when the auroral region is still exposed to sunlight.

The different heights of the upper limit of the various forms is closely connected with typical differences in the distribution of light intensity along the streamers. For arcs and drapery-shaped arcs the intensity maximum is situated a few kilometres above the bottom edge, and the intensity diminishes fairly rapidly upwards. In the case of draperies the point of maximum intensity lies higher and the diminution of intensity upwards is less rapid; in the case of isolated rays there is no pronounced maximum, they may maintain nearly the same intensity for hundreds of kilometres.

The Auroral Spectrum

Since Ångström in 1866 discovered the green auroral line, the spectrum of the auroræ has been examined by a great many observers, and many lines have been recorded, especially by Carlheim Gyllenskiöld.

Apart from the strong green line, all lines in the visible part are very weak and can only be seen with strong auroræ. Until 1912 when the writer began his investigations with large spectrographs of high light power, the observations and measurements were in a very unsatisfactory state. Spectroscopic measurements are very difficult to carry out; for the faint lines and the errors may amount to as much as 50Å. Spectrograms were obtained by A. Paulsen, Sykora and J. Westman, but with spectrographs of too small dispersion to give satisfactory measurements.

In 1912 the writer worked in Bossekop with a spectrograph having a dispersion five times as large as that previously used. The strongest part of the spectrum in the blue and violet part was proved to be composed of the strongest bands belonging to the negative group of nitrogen; a result which was confirmed by Lord Rayleigh in 1921. Measurements of the strong green line started at Bossekop and continued at Oslo, gave a wavelength 5577·6Å. This value which is right within a fraction of an Ångström, is nearly 8Å larger than the value generally accepted before the measurements were made. Slipher found a value 5578Å. On the basis of the values found by Slipher and the writer, Babcock measured the green line from the night sky luminescence, and increased the accuracy by means of an interferometer method. He found the value 5577·35Å which is probably right to within 0·01Å.

In 1922 the writer continued the spectral analysis under more favourable conditions, by means of a number of spectrographs, designed specially to suit the conditions of the observations. The instruments were put up on a platform at the Geophysical Institute at Tromsö, and the observations were continued there until 1926. The instruments had to be put into suitable boxes where the temperature was regulated automatically by electrical heaters. Some of the instruments as they were put up on the platform are shown on Plate III, Fig. 4

During this period a considerable number of lines was obtained on the spectrograms. The ultra-violet part was well explored and found to be composed mainly of bands belonging to the second positive group of nitrogen. (A spectrogram is shown on Plate II, Fig. 9) The second green line was obtained spectrographically (Plate II, Fig. 8, Line b′), and found to be composed of several lines close together with an average wave-length 5239Å.

In the red part a number of diffuse bands were observed which were referred to the first positive-group, and for various reasons the writer assumed that the red lower border of certain auroræ (red auroræ of type B) was due to enhancement of the first positive nitrogen group relative to the green line with increase of pressure downwards. A red line was found at 6300Å, and later observations with higher dispersion showed two lines in this region (6300Å and 6365Å). These red lines are for many reasons very remarkable. Some deep red auroræ for which the red colour extends to the very upper limit (type A) owe their red colour to the enhancement of these lines. By the end of 1926 about 50 lines and bands had been measured.

In 1930 the spectral work was continued under still better conditions at the new Observatory at Tromsö. New instruments were built, one of which is shown on Plate III, Fig. 2; Fig. 3 on the same plate shows two large spectrographs in their boxes on the observational platform.

The spectral work carried out during the last three years at the new Observatory has added largely to our knowledge of the auroral spectrum. Special attention has been paid to the exploration of the long wave part from infra-red to blue. In the infra-red the spectrum consists of a number of bands belonging to the first positive group of nitrogen, and more lines and bands have been measured in red and other parts of the spectrum. Spectra showing interesting bands and lines in red are shown on Plate II, Figs. 7 and 10, the latter taken with the large spectrograph shown on Plate III, Fig. 2, with an exposure lasting for several months. The

observations at the Auroral Observatory have already added 25 new lines and bands to those previously detected and measured, so the total number of known lines and bands now amounts to 85.

The origin of the conspicuous green line long remained a mystery. In 1924 the writer found that solid nitrogen gave a band which, in the presence of neon, was concentrated into a line with wave-length 5577·8Å, a value coinciding within the limit of error with the wave-length of the green line About a year later McLennan and Shrum detected a new oxygen line with a wave-length 5577·34Å, which they identified with the green auroral line. The interpretation of McLennan and Shrum at first met with the difficulty that a number of oxygen lines which ought to be present did not appear in the auroral spectrum. As shown by the writer the difficulty may be partly overcome by assuming that oxygen is excited to emit the green line by means of collisions of the second kind with activated nitrogen. This also gives an explanation of the large intensity of the green line. The interpretation of McLennan and Shrum is also strengthened by the fact that the two red lines 6300Å and 6365Å, responsible for the red auroræ of type A, are probably identical with two oxygen lines

Apart from the green line and probably the red lines mentioned, the auroral spectrum is dominated by the nitrogen band spectra, emitted partly from molecules, partly from positive molecular ions of nitrogen. The remaining lines are extremely faint and most can be referred to the line spectrum of nitrogen. A few lines may probably be referred to atomic ions of oxygen. No oxygen bands are observed, a fact which strengthens our view that the oxygen luminescence produced by direct excitation is very weak and that the green line, if due to oxygen, is excited indirectly through nitrogen.

Consequences of the Spectral Analysis

One first important result of our spectral analysis is that lines of the light gases hydrogen or helium are either absent or extremely weak. This shows that the layer of light gases which has previously been assumed to float on the top of our atmosphere does not exist. The result implies that, apart from the formation of ozone in the upper atmosphere, the composition of the atmosphere keeps fairly constant to its very top, the gases being mixed by translatory and turbulent motions.

From the development of the rotational components of the nitrogen bands the writer was able to determine the average tem-

perature of the molecular particles which emit the auroral luminescence. The first measurements gave a value of about −30° Centigrade, and as the excitation process may increase the rotational energy, this temperature derived from the band-spectra should give an upper limit for the temperature normally existing in the auroral region.

The writer found in 1923 that the intensity of the nitrogen bands relative to that of the green line increased upwards. As the green line can be followed to the very top of the streamers, this shows that nitrogen is the predominant component of the atmosphere to its extreme limit, and since also auroral rays can maintain a fairly constant intensity for hundreds of kilometres, it was concluded that nitrogen must be carried towards high altitudes through electric fields, acting on ionised nitrogen. This electrical state was found to be a simple consequence of the action of sunlight, of very short wave-length, on the upper atmospheric layers. The result is the formation of a lower layer with surplus positive and an upper one with surplus negative charge. Between these layers the electric force is directed upwards and the positively charged matter is lifted up towards higher altitudes

This state is dependent on the continual action of solar rays of short wave-length, and is only present on the day side of the earth As soon as the solar rays cease to act, the field is neutralised and the matter begins to fall to establish the night conditions. On the day side the atmosphere extends into a state very similar to the solar corona and which the writer has called the terrestrial corona This name was chosen to indicate that both the terrestrial and solar corona may be regarded as mainly produced by the action of sunlight of short wave-length resulting in the emission of high-speed electrons which is the primary process in the development of the coronal structure.

The terrestrial corona which has its largest extension in the direction of the sun, but is modified by the magnetic field of the earth, gave a simple explanation of the zodiacal light, which obtained its name just because it is a phenomenon which is connected with the ecliptic.

The zodiacal light should accordingly consist of sunlight, scattered by the terrestrial corona, but in addition the matter itself should emit bands and lines due to its excitation by the action of sunlight of short wave-length. This luminescence spectrum should be similar to that of the light from the night sky which may be mainly accounted for by the recombination process taking place during the night in the highest atmospheric strata, where

the ions or active states formed during the day, recombine very slowly.

The existence of the terrestrial corona on the day side of the earth is confirmed in a striking way by the fact already mentioned, that according to Störmer, the maximum upper limit of the auroral rays is larger at lower latitudes than in the Arctic regions and that the rays are much higher just after sunset than later in the night.

The writer has shown that the processes which are responsible for the development of the terrestrial corona and, at any rate partly, for the solar corona, give a simple explanation of the development and essential physical properties of the comets and their tails.

The study of the auroral spectrum combined with the height and light distribution of the ray streamers leads us to believe that several maxima of electric conductivity occur in the auroral region (above say 80 km); a conclusion in good agreement with recent results obtained from radio-echo work by Appleton, Tuve and others

The Properties and Origin of the Rays producing the Auroræ

From the height measurements of the auroræ together with estimates regarding the amount of matter existing above a certain altitude per square centimetre, we can calculate the energy which the solar electric rays must have in order to penetrate down to a certain altitude.

The writer found that α-rays with an air equivalent of 7 cm. corresponding to an energy of about 8 million volts stop at an altitude of about 77–80 km. Any type of positive rays would therefore need to possess enormous energy to account for the lowest auroræ. Rays of negative electrons having an energy of 20,000 electron volts, would be practically absorbed at an altitude of 100 km., and in order to account for the lowest altitudes observed (70 km.), electron rays with an energy of 130,000 volts are required.

In order to account for the distribution of light intensity along the streamers and its variations, the writer found it necessary to assume that the absorption of electric rays in the atmosphere is essentially influenced by the magnetic field of the earth, and that the individual rays turn round the magnetic lines of force. According to the angle the ray makes with the lines of force when it enters the atmosphere, it may be turned back towards space at different altitudes, and the distribution of the turning-points and points of

absorption will essentially influence the distribution of light intensity along the streamers. At the turning point the ray moves in a circle perpendicular to the lines of force and from the minimum thickness of the auroral streamers, the writer found that the magnetic stiffness $\left(\frac{mv}{e}\right)$ must be smaller than 10^4 If at the same time the rays have a sufficient penetrating power to account for the altitude of the auroræ, the above-mentioned conditions can only be fulfilled by electrons, because positrons of that energy and abundance cannot come into consideration.

The hypothesis of Birkeland was criticised by Schuster, who found from theoretical considerations that bundles of electric rays would be prevented from leaving the sun on account of the electromagnetic forces set up, and that the electrostatic forces would prevent the rays from keeping inside a limited bundle.

The writer showed that these difficulties could be overcome by assuming that the sun emits both positive and negative rays. The electric ray bundles are supposed to be composed primarily of negative electrons, but the track is neutralised by positive ions. Such a ray bundle will be deviated in a magnetic field essentially as a bundle of negative rays, and the electron rays in the bundle will mainly determine its penetrating power. The moving positive ions may partly influence the magnetic deflectibility of the bundle as a whole and account for the fact that the angular radius of the auroral zone is larger than we should expect if the ray bundles were entirely composed of electrons.

The ray bundle although electrically neutral must not be magnetically neutral, because we know from the distribution of auroral frequency round the magnetic axis point, that the rays must be deflected in the magnetic field of the earth, and that this state of things must exist at distances large compared with the dimensions of the earth.

Regarding the physical processes on the sun which may account

EXPLANATION TO PLATE III

FIG 1.—Auroral camera of the Störmer–Krogness type with slide arrangement for taking six pictures on one plate.

FIG. 2.—Large glass spectrograph constructed by Vegard for the new Auroral Observatory at Tromso. The instrument may be adjusted to give maximum light power for any desired part of the spectrum.

FIG. 3.—Observational platform of the Tromsö Observatory, after snowfall. Boxes containing large spectrographs are seen in the front. A stand with clock and switchboards is seen at the back.

FIG. 4.—Picture (1922) of platform on the roof of the Weather Bureau Building at Tromsö showing two boxes containing large spectrographs and one of the small spectrographs.

for the emission of these ray bundles, we are on somewhat uncertain ground. Arrhenius and later Milne have proposed the hypothesis that streams of matter may be driven out from the sun on account of the radiation pressure. Ray bundles formed in this way cannot give sufficient penetrating power to account for the observed auroral altitudes, and they would be essentially neutral ray bundles which cannot come into consideration for the explanation of the properties of auroræ and the polar magnetic disturbances.

Some years ago the writer suggested that the ray bundles come from solar matter of high energy brought towards the surface through the vortex motions which manifest themselves in the sunspots. These lumps of active matter, which may maintain their activity during several revolutions of the sun, may emit rays of short wave-length, of a kind similar to X-rays, and give high velocity electrons through photo-electric action. The rays may be concentrated into bundles by the influence of electric and local magnetic fields on the sun, and they may be neutralised by positive electrons which are drawn into their track by electrostatic forces. The bundles are formed in a similar way to those of the solar and terrestrial corona, and the streamers of the solar corona are probably closely related to those ray bundles which are responsible for the northern lights. This view is supported by the fact that the red auroræ of type B, which on account of their low altitude are produced by rays of high velocity, seem to appear at sunspot minimum when the coronal streamers obtain their maximum length.

THE PLACE OF CHEMISTRY IN HISTORY [1]

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I do not claim to be an expert in history, but occasional excursions into that field lead me to believe that the historian of to-day does not view his subject from quite the same angle as his not very distant predecessor Kings and princes, revolutions and wars and treaties, claim a smaller proportion of his pages, while markets and trade, the inexorable pressure of economic law, and the effect of such factors on the life of the common people, appear clothed with an importance scarcely realised by the chroniclers of the past.

Occasionally one may even find references to great scientific discoveries, and it is interesting to speculate whether the historian of A.D. 2000 may not find it necessary to weave the threads of science, as well as those of economics, through the web of his history.

" The place of science in history " would be a subject of wider interest than that which I have chosen, but, since the cobbler should stick to his last, I have elected to deal with that branch of science only with which I am best acquainted I should like, however, to disarm the criticism of my colleagues who find their special fields invaded by confessing that I use the word " chemistry " in the widest sense, embracing medical chemistry, physical chemistry, and other allied subjects.

But do you seriously suggest that chemistry has had much influence in human history ?

You ask your question in good company.

Nineteen hundred years ago Pliny, who could hardly be accused of being hostile to science, wrote that " he would have given his readers some information about the technique of using dyestuffs, if dyeing had ever been regarded as one of the liberal arts "—a pursuit worthy of a free man.

Sir Clifford Allbutt, in his *Science and Medieval Thought,* wrote :

[1] Presidential Address delivered to the Dublin University Experimental Science Association on November 7, 1933.

"Even in the seventeenth century we find in Oxford that Boyle was bantered by his friends as one 'given up to base and mechanical pursuits.' As Boyle himself puts it in his delightful way—'. . . There are some that are troubled when they see a Man acquainted with other learning countenance by his example sooty Empiricks . . . whose experiments may indeed be useful to Apothecaries, and perhaps to Physicians, but are useless to a Philosopher that aims at curing no Disease but that of Ignorance.'"

To take a more recent example, it is not many months since one of the most eminent of my literary colleagues said to me, "Oh, I grant you that you chemists have added somewhat to our comfort, just as plumbers have, but that the study of chemistry can be regarded as a part of a liberal education I could never admit." Even if I were to claim that the historian should take account of chemistry because he, if anyone, should subscribe to the dictum of Terence's Chremes, "*Homo sum: humani nil a me alienum puto*"—"I am a man, and all the concerns of man are my concerns"—my classical tag would scarcely prevail on my colleague to regard my subject in any other light than that of a *tour de force*.

And yet I submit seriously that the influence of chemistry on history has been and is profound, and that this influence has not been merely in things material.

Let me try to summon before the eye of the mind a series of pictures.

Picture the first: the medicine man of the primitive tribe is seen trying to cure dysentery or malaria or elephantiasis by the shedding of innocent blood, or an incantation, or a charm hung about his patient's neck.

Picture the second: the civilised physician of the early centuries seems to be better provided with weapons and has his textbooks—Heracleides of Tarentum, Scribonius Largus and the like. As he pores over them, he finds, side by side with alum and soda and turpentine, clothed with equal authority if more difficult to obtain, remedies such as camel's brain and gall, tortoise's blood, or the liver of a dead gladiator

Picture the third: in 1526, or thereabouts (for there is some doubt as to the exact date) we see Wilhelm Bombast von Hohenheim, better known to us as Paracelsus, commencing his lectures in Basle by a dramatic conflagration of the works of Avicenna and others. Part knave, part madman, part genius, he is hard to assess. Disappointed by the orthodox University chemistry of his day, he has come in contact with practical chemistry—the chemicals

of Nature and the methods of purifying them—in the mines of the Tyrol. He lectures now in German, not Latin—his impudence clearly knows no bounds. He overwhelms with abuse those who accept unquestioningly the authority of Galen and Avicenna—dead centuries before. For their systems he substitutes one almost as strange, but what matter! He cries out to the alchemists to divert their energies from the quest for the philosophers' stone to the preparation of chemical substances useful in the treatment of disease. With uncertain steps the new road is trodden, but at least it is open.

Journey's end is still far off. In 1685 a king lies dying. Charles II, overtaken by Nemesis at last, is seized with convulsions and lies ill of what Raymond Crawfurd [1] identifies as a form of Bright's disease. He is bled freely Noxious plasters are applied to his feet. Next follows a preparation of cowslips and sal-ammoniac, and an anti-spasmodic julep of Black Cherry Water, Peruvian Bark too (the source of quinine) is administered. As the royal patient disimproves, Raleigh's antidote is tried, "the virtue of which resided more in the multitude of its ingredients than in their potency, for it was an extract made from the various parts of an incredible number of herbs, portions of animals, and animal products such as pearls, corals, and bezoars." Later "the Oriental bezoar stone (a concretion of ellagic acid), from its normal habitat in the stomach of an eastern goat, was transferred to its last resting-place in that of the King." The climax of this desperate treatment was the administration of "Spirit of Human Skull;" one form of which was known as "The King's Drops," and was said to have been perfected by King Charles himself. The variety employed in convulsive disorders was prepared by digesting for twenty days spirits of wine and sage with the fragmented skull of a man who had died a violent death, and then distilling the liquor.

Some of these prescriptions were signed by as many as fourteen of the most eminent physicians of the day. Strange fate for one who, with all his faults, was interested in chemistry!

The next picture may have been seen by some of you among the historical exhibits at this year's meeting of the British Medical Association in Dublin. It is a contemporary water-colour of an operation, performed a century ago by an able surgeon on a conscious patient. The knife was clean no doubt—as far as the eye could see. The artist has appended a brief note, "The patient died a fortnight later."

[1] *The Last Days of Charles II.*

What a change since then! Louis Pasteur, a Professor of chemistry though more than a chemist, discovers the existence in the air of germs which are capable of fermenting grape-juice, souring milk, and causing wounds to suppurate. The application to surgical practice is clear. The chemist has been in attendance at every step, providing one antiseptic after another. He has produced, too, the anæsthetics, ether, chloroform, nitrous oxide, which, in the hands of Simpson and others, before and after, have made operations less terrifying and safer. Not so often does the patient die a fortnight later.

The twentieth century has seen the persevering chemist isolate insulin to give new hope to the diabetic and discover the existence of vitamins and thus the causes of a number of puzzling conditions. At the moment a band of skilful workers are trying to elucidate the chemical nature of the vitamins and, in at least two cases, their efforts seem likely to be crowned with success.

"This," says my hypothetical critic, "only proves that chemistry is of importance to medicine, but where does history come in?"

What is history but the story of the doings of humanity? What are more intensely human than health and sickness, misery and comfort, life and death? A remedy correctly applied at the correct moment might have far more than individual results. Twenty years more life to Alexander might have changed the course of history.

It is one of my most obvious tasks to-night to point out that chemistry has changed man's material environment. I shall therefore consider briefly the history of two chemical substances.

Perhaps the most important of all constructional materials is iron. Its preparation from its ores involves a definitely chemical process, that of reduction, and one which was not available to our early ancestors.

Hesiod, in his *Works and Days* (lines 148–51) describes primitive men, of mighty strength, "and their armour was of copper, their homes were of copper, and with copper they tilled the land, for as yet there was no black iron."

We find, therefore, that iron, when won with difficulty, was very highly valued, and a piece of iron figures more than once in Homer, side by side with oxen, women, tripods, and other important commodities, as a prize for victory in the games.

This new and strange material, probably used for tools and weapons before it was employed for building, had one serious disadvantage. Pliny, who was apt to moralise more than is customary for scientific writers nowadays, having described iron

as "at once the best and the worst servant of humanity," and "minister of war, murder, and robbery," goes on to remark with grim satisfaction, "The foe of iron is the customary benevolence of Nature which exacts from it this penalty, that it must needs rust and, with equal foresight, decrees that that which inflicts most loss on short-lived humanity shall be of all materials the most short-lived."

The history of iron for 2000 years has been largely the history of endeavours to prevent it from rusting. The simplest and most obvious method has long been employed—the covering of iron-work with paint—a combination of finely-ground pigment and oxidisable oil A second method has only recently been understood. Very pure iron shows a remarkable immunity from rusting, and resistant iron of 99·9 per cent purity is commercially available to-day. The modern chemist was anticipated in this in at least one notable instance, and our belief in our technical superiority is a little shaken when we think of the unknown Indian metallurgist who produced the iron pillar of Delhi—six tons of iron standing in the open for sixteen centuries unrusted. Even the dry climate of India could not have guaranteed such freedom from corrosion, but an analysis has shown that the pillar consists of 99·7 per cent. iron. A third method of protecting iron is entirely modern. If iron is alloyed with suitable amounts of other metals, notably chromium, steels can be produced which show wonderful resistance to the attacks of air and moisture. The production of stainless steels is one of the greatest triumphs of metallurgy, and they are replacing ordinary steels in knives, door-fittings, golf-clubs, grates, ornaments, and countless other luxuries and necessities.

Let us now turn to another metal—the familiar aluminium. This element occurs abundantly in the earth's crust, for clay consists largely of complex silicates of aluminium, but the early metallurgists who produced copper, lead, iron, tin, and mercury from their respective ores, and their successors who wrung from Nature nickel, cobalt, and many other metals, were unaware of the existence of aluminium. Even in the late eighteenth and nineteenth centuries, when the chemists of the day, with their ever-widening knowledge, inferred by analogy that alumina, the base of the well-known alum, must contain a metal, the task of isolating the latter proved difficult, and as great an experimentalist as Sir Humphry Davy had to confess failure. It was not until 1827 that Wöhler first isolated aluminium at Göttingen, by heating its chloride with potassium. One improvement followed another in processes involving potassium and later sodium as reducing agents, until the patents

of Hall in America and Héroult in France inaugurated the use of the electric furnace with its charge of alumina and cryolite. Aluminium, which had cost about 60*s*. a pound avoirdupois in 1858, fell to 4*s*. a pound in 1891.

In almost every household stainless steel and aluminium articles are now to be found. Is this fact beneath the dignity of the historian? Rather more than half the individuals of the human race are women and a considerable proportion of these, even in the twentieth century, are occupied with the care of the home. To these home-makers the stainless steel and the light and permanent aluminium of the chemist have come as an inestimable boon to lighten their labour and shorten their hours of work. Some of them, perhaps, will use the leisure thus gained in ways which will force themselves on the notice of the economist and the historian.

To attempt to enumerate the ways in which the chemist has affected our everyday life would be a thankless and interminable task. Evidence of his handiwork meets us in every room, in every street, and all over the countryside. He purifies the water we drink and supplies it with iodine if it does not contain enough of that element to prevent the incidence of goitre, he produces from unpromising materials such as coal-tar dyestuffs of every shade with an amazing resistance to the fading action of air and light, he metamorphoses solid fuels into liquid fuels if the needs of the moment demand them, he produces artificial fertilisers so that two blades of grass (or ears of corn) may grow where one grew before, he helps the husbandman, here and in the tropics, to combat the pests which attack his crops by supplying him with insecticides and fungicides—compounds of copper and arsenic, hellebore and nicotine and pyrethrum, and within the past decade rotenone from derris root

I should like to halt for a moment to consider two points with regard to this war on plant diseases. Both are gleaned from papers published as recently as September, 1933.

The compound rotenone, from derris root, discovered early in the century by Japanese chemists, is now much used as an insecticide in the United States of America. It suffers from the disadvantage that when applied to foliage, it is gradually oxidised to inert substances, especially in direct sunlight. Many derivatives of rotenone are more stable, but all are inert as insecticides with the single exception of the dihydro-derivative. The preparation of this substance sufficiently cheaply to make it of commercial interest proved difficult. One of the commonest ways of adding hydrogen to unsaturated organic substances involves the use of

nickel as a catalyst. Unfortunately hydrogenation in presence of ordinary nickel catalysts gave very little of the desired compound. At this point we encounter again an element which we have already viewed from a different angle. An alloy of aluminium and nickel is prepared, the aluminium is dissolved away with soda, and the resulting nickel is found to possess unusual catalytic powers. The catalyst thus prepared (a very recent discovery) hydrogenates rotenone to the desired compound at ordinary temperature and under ordinary pressure.

The second of the two papers dealt with the use of hydrocyanic acid for the fumigation of citrus trees. The citrus trees of Southern California are attacked by black, red, and purple scale insects. These, like almost all forms of life, are readily destroyed by hydrocyanic acid The thing that seems amazing to anyone acquainted with the extreme toxicity of pure hydrocyanic acid is that the process of manufacture and fumigation can be safely carried out

Nevertheless, in the factory described, the pure substance has been prepared at the rate of 650 pounds an hour for fourteen years without a single fatality. More than that, this intensely poisonous liquid has to be transported long distances by road in specially constructed steel trucks to the orchards, where each tree is covered by a tent, the cubic capacity of which is estimated before a carefully calculated quantity of hydrocyanic acid is pumped into the enclosure, and left for about an hour to do its work. That such operations can be carried out on a large scale without serious accident is evidence of good organisation as well as good chemistry.

The list of the chemist's practical services is far from being exhausted. Electric batteries, whether the small ones which light our flash-lamps or the large ones which drive our trains, are chemical systems and the investigation of them has been proceeding actively for many years and still continues. The cult of beauty, with its powders and creams, its lotions for hair-waving and hair-setting, utilises the chemist's skill, and he is responsible for most of the progress since the long-distant days when antimony and rouge (ferric oxide) were the chief cosmetics. The food we eat, the clothes we wear, the roads we walk on, the neon signs which dazzle and perhaps annoy us, and the cinema which distracts us—all bear evidence of the chemist's hand. His activities have so interpenetrated civilisation that we are hard put to it to imagine a world without him.

I have tried to demonstrate that chemistry is of the greatest importance to the material fabric of our modern life, but history

concerns itself not merely with things and actions, but also with ideas, and I must now attempt to justify my assertion that the influence of chemistry has not been solely in things material. Has chemistry filled any real place in the thoughts of men other than the chemists themselves ?

I think it probable that the thought of mankind in general was first markedly influenced by chemistry in the fifteenth, sixteenth, and seventeenth centuries, while chemistry was still alchemy. I do not mean to suggest that the intellectual processes of many individuals had not been affected before that, but ordinary folk, even in the more civilised communities, cannot have been much interested. Little by little, however, the attractive nature of the objects which the alchemists pursued drew general attention, for they were the philosophers' stone, which would turn base metals into gold, and the still more to be desired, though less fervently believed in, elixir of life. I do not claim that the interest thus aroused was healthy—to many it was a source of excitement, a stimulus, comparable to gambling on the Stock Exchange, or buying sweepstake tickets, or backing greyhounds or horses—but there can be little doubt that it was a widespread interest.

We know more of the dealings of alchemists with royalty than of their relations with the common people, but that is largely because the doings of royalty have been more carefully recorded. Alchemy was long banned in England except under licence, and Henry IV, Edward IV, and Henry VI all granted licences to alchemists. The great Elizabeth Tudor engaged Cornelius de Lannoy to produce 50,000 marks of pure gold annually at a moderate charge, but, like modern investors who wish to get rich quickly, she seems to have got little return on her original outlay, for we shortly find Cornelius lodged in the Tower of London where he may have perished, for aught we know.

In the sixteenth century it was almost the normal thing for kings and princes to maintain laboratories, and even to perform chemical operations themselves. A few of these royal alchemists deserve mention.

Prince Augustus I of Saxony, who reigned from 1553 to 1586, seems to have actually claimed to have discovered the secret of transmutation.

Rudolph II, who was Emperor from 1576 to 1611, had a house in Prague equipped as a laboratory, and for years that city swarmed with alchemists from all parts of the world. The director of his laboratories was Dr. Thaddeus von Hayck, whose duty it was to distinguish between the true alchemists and the impostors, and

to unmask those who used double-bottomed crucibles with gold hidden in the space between, or who added chemicals containing concealed gold during the operation. One of the most picturesque episodes in sixteenth-century Prague was the arrival of an imposing and apparently wealthy Arab, who claimed for himself mighty powers as an alchemist. Courtiers and merchants flocked to meet him, and one day he gave a feast to four-and-twenty guests to whom he announced that he was prepared, as a special favour, to convert 100 marks in gold into 1,000 marks for each one of them. As credulous as their royal master, they made haste to bring 100 marks apiece and the Arab led the way to his laboratory, where the furnaces were already glowing and the apparatus ready. Into a large crucible he put a great variety of chemical ingredients and, apparently, the 2,400 marks Scarcely had the bellows been applied to the fire when a terrific explosion took place, live coals were hurled everywhere, and the laboratory was filled with choking fumes. When these had cleared away the Arab (and the gold marks) had disappeared for ever.

The Emperor Ferdinand III, who reigned from 1637 to 1657, was another imperial alchemist. After Richthausen of Vienna had, so he claimed, transmuted three pounds of mercury into two and a half pounds of gold in 1648, Ferdinand purchased from him the secret of the philosophers' stone, and created him a Baron. Some of the gold was used for striking a medal to commemorate the occasion and the medal is still preserved in Vienna.

The interest of Charles II of England in alchemy has been already mentioned, and I have no doubt that experiments were performed in his laboratory by his cousin also who had some real right to be regarded as a scientist, the dashing cavalryman Rupert.

Although many of the alchemists were charlatans, trading on human greed and credulity, and paying with their lives when they tried too far the patience of their noble patrons, some were men of great ability and with a wide knowledge of chemistry. It is related that Francesco Borri, a well-known Italian alchemist, when under arrest for heresy in 1670, was brought secretly to the Emperor Leopold I, who had been ill for some time. Borri immediately detected an abnormality in the colour of the flame of the candles which illuminated the Emperor's room, and was able to show that they contained arsenic, with the vapour of which the Emperor was being slowly poisoned. The cause once removed, the Emperor recovered and lived for many years, but alas, after holding Borri for a time in honour, he eventually handed him over to his enemies.

As alchemy slowly melted into chemistry, as the search for the philosophers' stone was abandoned in favour of attempts to produce pure chemical substances, ascertain their properties, and discover the laws which govern their behaviour, popular interest declined. The new chemistry did not entice the cupidity of the populace nor arouse their envy, fear, and superstitious hatred like the old, and the eighteenth-century chemist was less likely than his alchemical predecessor to languish in prison or die on the gallows.

The influence of the experimental sciences over intellectual processes in general has been so great that it is not easy to know what instances to select when such must be few and brief. The most important contribution of such sciences probably lay, not in the performance of miscellaneous experiments, which goes back to pre-Aristotelian times, but in the detection and demonstration of a connection between a number of phenomena, and the justification or disproof of a hypothesis by a carefully planned series of experiments, designed for that very purpose. As Sir Clifford Allbutt pointed out, the greatness of Roger Bacon consisted in the fact that he emphasised the importance of the experimental *method*, as distinct from the carrying out of casual experiments.

Passing on rapidly from this general idea, I propose to select two examples of chemical influence on our outlook. It is only within the past century that we have become familiar with the idea that lordly man may be investigated by methods similar to those applied to the lower animals and to inanimate nature. The application of scientific methods to ourselves has brought in its train a major revolution of thought. The line of investigation which attracted most public attention in the nineteenth century was undoubtedly the theory of evolution, usually associated with the name of Charles Darwin, and the storm of controversy which raged is sufficient proof of the interest aroused. Even before Darwin, however, chemistry had been encroaching on the same dangerous and exciting ground.

Most chemists in the early nineteenth century divided chemical substances into organic and inorganic, using the terms in a slightly different sense from that current to-day. Organic substances were those known to be produced by living organisms and not known to be produced elsewhere, and it was generally believed that, although organic substances could be isolated and used, they could not be synthesised in the absence of what was termed "vital force." In 1822 Berzelius, possibly the leading chemist of the day, wrote: "Within the sphere of living nature, the elements

obey laws totally different from those which obtain in inanimate nature. . . . Organic substances cannot be prepared artificially." The first blow to this hypothesis had already been dealt a year earlier, when Hennell synthesised alcohol, but this achievement seems to have attracted little attention, possibly because alcohol did not strike Hennell's contemporaries as a typically "organic" substance. In 1828, however, Wöhler synthesised urea, a recognised product of animal metabolism. He was not slow to see the importance of his discovery, and wrote triumphantly to a friend, "I must tell you that I can prepare urea, without requiring a kidney or an animal, a man or a dog." Wöhler's famous experiment was followed rapidly by the synthesis of most of the simple compounds of carbon. Many of the more complex organic substances still defy our efforts, but few chemists doubt that even complicated bodies like proteins will eventually be synthesised.

The daring thought has been suggested that, if we could synthesise sufficiently complicated organic substances, and put them together in the right proportions, the resulting material might possess the peculiar property of Life. I do not suppose that most chemists anticipate such a sensational result, but we are not likely to be in a position to make the experiment for a long time to come.

Has chemistry rendered man a service in helping to bring about such a shattering change in his outlook? Were men not happier before subversive ideas and doubts assailed their confident serenity? Hard questions these to answer! The conflict between science and religion has raged bitterly in the past, but its sounds are now seldom heard. Increased insight into the Divine plan does not prevent one from worshipping its author. Scientists are often devout and preachers use the discoveries of science to point a moral in their sermons. There is a growing belief that, however differently she may appear when approached from different angles, like a mountain whose northern side is set with frowning crags, while the southern slopes gently to the valley, Truth is one and will prevail.

The second instance which I choose is of more recent date.

The discovery of radio-activity has led to a more profound exploration of the structure of matter than the most optimistic of an earlier generation of scientists would have dared to hope. The man in the street (or more likely in his arm-chair of an evening) has become aware of this work and interested in it on a scale scarcely paralleled even by the nineteenth-century interest in Darwinism. Not merely are the popular papers compelled to

include articles on such scientific developments, but we have the gratifying and amazing spectacle of scientific books becoming best-sellers. It is, to my mind, one of the most significant happenings of our time that works such as those of Jeans and Eddington which, although intended for popular consumption, demand nevertheless persevering and intelligent attention, should be sold by the hundred thousand.

The habits of thought of the readers cannot fail to be influenced by such a course of reading. Provided they do not merely gape in vacant wonder at the mysteries of the infinitely great and infinitely small, provided they follow to some extent the carefully planned campaigns in which scientific workers attack scientific problems, their powers of discrimination should be increased, and they should be more capable of distinguishing the true from the false, the genuine from the specious, in what is laid before them, whether it be a reassuring advertisement for a patent medicine or the glowing promises of a political party.

The forces developed in many chemical reactions are so great, the products so important, that it is not surprising that chemistry is playing a decisive part in some of the problems of the twentieth century. This is especially true of the two chief spheres in which men come into conflict—war and trade.

Chemical warfare is not new. At the sieges of Plataea and Delium in the fifth century B.C. combustibles such as pitch and sulphur were used in trying to set fire to wooden walls. In 69 B.C. the defenders of Tigranocerta rained blazing petroleum on Lucullus and his attacking soldiers, and most known combustibles were used at one time or another under the general name of "Greek Fire." The next important contribution of chemistry to warfare came with the use of gunpowder, dependent in its turn on the discovery of reasonably pure saltpetre. Roger Bacon was aware of the explosive power of saltpetre mixtures, but I know of no proof that he contemplated their use for propulsive purposes. By the fourteenth century, however, guns and gunpowder were in common use. From these humble beginnings have developed the multitude of high explosives, propellants, and detonators which have added new terrors to war. Lyddite, T.N.T., amatol, have been followed by the poison gases (methyl chloroformate and the like), the tear gases (such as xylyl bromide), the sternutatory gases (such as diphenylchlorarsine), and mustard gas (dichlorethyl sulphide). These gases, or volatile liquids, used in the Great War of 1914–18, will no doubt have even more terrible successors.

It is probably no worse to be poisoned in the twentieth century

by a toxic gas than it was to have one's body rent asunder in the nineteenth by a bursting shell, or pierced in the eighteenth by a bullet, nor indeed am I sure that these fates are much worse than death by the cut-and-thrust methods of earlier warfare, but there is undoubtedly a cumulative effect, and the total destruction which can be achieved in a short time is probably greater now than at any period in the world's history. It is true, of course, that chemistry also takes part in the defence, and the boxes attached to gas-masks are chemical store-rooms, the result of brilliant and patient investigation.

When we turn to the economic battle-field, we find that the twentieth-century advance of the sciences, and chemistry foremost among them, has produced a situation which seems at first sight unparalleled in history, although in fact, during the industrial revolution of the nineteenth century, the proportion of unemployed in England was probably greater than at present, and their lot very much worse One of the most spectacular successes of the chemist has been the fixation of the nitrogen of the air in forms in which it can promote the growth of plants, and agriculture is very dependent on chemical support. A recent writer, discussing one such process—that of Casale for fixing nitrogen as ammonia (a variant of the Haber process)—states that the process has now been made so successful, so simple, that in some factories no chemists are now employed, the entire work of supervision being accomplished by a single engineer. "Chemists," he concludes rather bitterly, "have solved the nitrogen problem so successfully as to render unnecessary the employment of members of their own profession." This is but one case among many. Even when the temporary causes of the present world-wide depression have spent their force, it will remain true that in many departments of industry three men can produce as much as five could a very few years ago, and some means must be found for preventing the permanent unemployment, with its appalling results, of a considerable percentage of our fellow-men.

It is some time since I evoked my shadowy critic, but I can imagine him saying, "This last part of your address, while proving perhaps that chemistry is interfering in history in no uncertain way, seems to me a most damning indictment of your science." This is a hard saying, and it seems inadequate to answer that most chemists are respectable people who pursue knowledge for its own sake, and that they should not be held responsible if ambitious generals or greedy industrialists use the new knowledge to the disadvantage of the race.

A detailed defence would take a longer time than is considered proper for a presidential address, and would demand greater patience than my audience can be expected to show. It would consist essentially in a review of the history of humanity as a whole, with chemistry taking there its appointed place. Macaulay, when discussing the revolt against Charles I, says, "On both sides there was, undoubtedly, enough of crime and enough of error to disgust any man who did not reflect that the whole history of the species is made up of little except crimes and errors." Without going so far as Macaulay, I might say that the whole history of the species is made up of crises which must be faced, and problems which must be solved. In days gone by there were wild animals which must be tamed or annihilated, barbarians who must be assimilated, plagues which threaten to ravage continents and against which safeguards must be found, political readjustments rendered necessary by the increasing awareness of the people that they possessed rights and that they had the power to assert them, the gradual realisation of the wrong involved in the enslavement of millions of human beings—these are but a few of the crises of the past which have been survived, the problems which have received at least a partial solution.

It is doubtful if the prevention of war and the reduction of unemployment seem more difficult to us than the abolition of slavery did to our forbears, and the species which has solved one problem may solve the others also. The addition of chemical weapons to the armoury of war does not alter that problem much—it makes it more urgent.

The blame for the simultaneous existence of poverty and plenty cannot justly be laid at the door of chemical or other science. The scientist who provides the plenty feels that it is not unreasonable to expect the politician and the economist to ensure that the supplies shall be distributed. If he enables work to be done by a smaller expenditure of human energy, he considers it the difficult duty of the politician and the economist to devise a system in which more leisure for all will result, rather than feverish activity for some and complete unemployment for others.

The scientist can claim further to have forged the powerful weapons of scientific method, which are at the disposal of the politician and economist, and the latter at least is now using them.

Here is the great problem for twentieth-century man, one worthy of all his skill and patience—to alter the fabric of civilisation to suit the changed conditions of life, changed in great degree by the advance of scientific knowledge. I will conclude by quoting the

final lines of a recent editorial in *Nature*: "The time has come for the civilised world to readjust itself to meet the new conditions if it is to be saved. Whether men will prove themselves worthy of the argosies of science which will enter their ports is not for us to predict, but upon the result will depend the future destiny of the human race."

GEOGRAPHICAL FACTORS IN THE STUDY OF MAN

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In this article I intend to try to give some indication of the main geographical factors which must be taken into account in the study of human societies and their development. It is obvious that Man is dependent on the earth for the materials wherewith to satisfy all his physical needs, and that the surface features affect all his movements about the earth; while its climates influence all his activities. For the present purpose it is useful to group the geographical factors under these three headings, *viz.*

I The distribution of the materials Man uses—for food, for shelter, for the tools with which he shapes these materials to his purposes, and for luxuries;

II Those features which influence his movements about the earth's surface. For the extremely uneven distribution of the natural resources on which he is dependent is such that all effective use of material resources involves transport;

III Climate and weather, which directly affect his health and energy and also influence him indirectly through the vegetation and in other ways;

and then to make a rapid survey of some few outstanding aspects of human development, with reference to these factors. The actual, and still more the relative, importance of several of these factors has varied in different stages of human culture; and in general the complexity of the relations has increased with the advance of civilisation.

In the hunting stage of Man's cultural development his food supply was limited to what he could find or catch, on the land or in the water. The pursuit led our primitive ancestor into all the habitable lands of the world, with the exception only of a few remote oceanic islets, and made him the most widespread of all animals. But hunting is a precarious mode of subsistence. Even

at its best, in such good hunting grounds as the eastern lands of North America just before their colonisation by white men, it seems that the maximum population supported by hunting, together with some primitive agriculture, did not reach an average of one person per square mile. And probably there were fewer than half a million aborigines in Australia when it was discovered. Among such scanty populations, wandering in small groups, little progress was possible; while the hunting life is distinguished by the fact that improvements in it must ultimately destroy it. The more efficient the hunters become the more rapidly do they destroy the animals on which they depend.

On the grasslands in the centre of the Old World there were many animals capable of domestication; and here Man passed from the life of the hunter to that of the pastoralist. Nearly all the more important of our domestic animals [1] are natives of central Eurasia, and were first domesticated there. No other region had animals equally suitable; and in no other part of the world did the pastoral life become important until Man took some of these Old World domestic animals with him in his migrations. An indication of the value of such animals in relation to Man, and of the importance of their native geographical distribution, is given by a comparison of the conditions in Eurasia with those in Australia. In the latter region the principal native animals are marsupials, of which the kangaroo is the largest. These are obviously useless as beasts of burden, and, of course, do not supply milk; hence the Australian aborigines had no opportunity of passing into the pastoral stage of development; the native vegetation was equally poor in plants suitable for cultivation for food supplies, and so the people remained hunters and gatherers of food until white men colonised Australia.

The domestication of the grass-eating animals in the interior lands of the Old World gave rise to one of the most important and distinctive types of human society, that of the pastoral nomads. The dependence on herbivorous animals led to regular seasonal migrations. The need of guarding the herds and of moving regularly gave rise to a semi-military organisation and great mobility. The size of the herds was limited by the amount of vegetation available within feeding range; and the herds were usually small. But a small herd can provide food for only a small number of people; and so the nomads moved and lived in small groups. The use of horses, and the dependence on moving animals, gave these societies great mobility within the grasslands and enabled them to

[1] Including the ox, ass, horse, sheep, goat, and camel.

extend their range over almost the whole of the vast areas between Central Europe and China, from the northern forests to the southern deserts or jungles.

Elsewhere the search for a more secure food supply led to the cultivation of plants, and so to the development of agriculture. This gave a more reliable and more abundant supply of food than did pastoral nomadism. It fixed the cultivators to the soil. And at once it enhanced the value of fertile and cultivable lands, and so gave greater importance to their geographical distribution. In good lands agriculture can produce a surplus beyond the immediate needs of the cultivators ; so it made possible the accumulation of wealth and the beginnings of civilisation. It is significant that the earlier Old World civilisations of which we have records all lie within a narrow zone of latitude, between 25° and 35° north of the equator, in regions of long hot summers, with a long dry season which prevents the growth of any dense forests, and in the valleys of rivers subject to annual flooding. Only where the soil fertility was naturally renewed by river silt was it possible to have permanent agriculture before Man learned the methods of fallowing or manuring. These lands of early civilisation are those in which it was easiest to establish a permanent agriculture.

Where agriculture and pastoralism came together the former profited by the introduction of work-animals, particularly the ox for ploughing. But also there developed an inevitable conflict ; since the cultivator and the herdsman desired to use the land in ways that were quite incompatible. The dispute between the herdsman, who seeks grazing for his animals, and the cultivator, guarding his growing crops, is older than history. It has been a main cause of human conflict from the time of Abel and Cain to the present-day disputes between ranchers and farmers in the marginal lands of agriculture in the New World. To the settled agricultural peoples whom they raided, and sometimes conquered, the pastoralists brought different forms of social organisation and a greater intercourse with the rest of the world.

The possible areas of cultivation of any plant are strictly limited by a number of geographical factors, among which those of climatic distributions are most prominent. Man was thus compelled to depend on different food staples, and therefore to follow somewhat different forms of agriculture, in the several major regions in which the Old World civilisations developed. The rice culture of the valleys of south-eastern Asia provides an economic and social basis for society markedly different from that given by the cereals of Europe. Nearer to one another, but yet differing in some important

respects, are the mixed cereal and tree culture of the typical Mediterranean coasts—the land of corn and wine and oil—and the mixed farming and animal husbandry of the areas to the north of the Alps—a land of bread and beef and beer.

The materials needed for shelter were for long ages obtained locally in almost every land. Houses were built of wood, or mud (later brick), or stone. Tents and clothing were of skins, or of fabrics woven from animal or vegetable fibres. All these materials were widespread; and hence the variations in their distribution were of less importance before the modern age than those of food materials. But the amount of shelter needed, and so the energy to be expended to obtain it, is closely dependent on the climate. The Canadian needs more fuel and clothing and housing than the Hindu, if he is to live in health and comfort.

The materials for the making of tools are much more varied, and much more unevenly distributed, than those already referred to; and they are equally essential to any developed human culture. As soon as our remote ancestors began to shape stone tools the distribution of deposits of suitable stone became a matter of importance to them. The flint deposits in the chalk of our own country had an influence in the neolithic civilisations analogous to that of the iron ore deposits to-day. The distribution of the ores of copper, and of tin or antimony, needed for the making of bronze, was one of the factors determining the far-reaching routes of commerce and cultural intercourse of the Bronze Age.

Human culture has advanced as Man has learned to use better tool material and to make more efficient tools. So he passed from the Ages of Stone to that of Copper, and then to the Bronze Age, thence to the Age of Iron, and later to that of Steel. And within the present generation there have been developed numerous alloys which have become essential to the tool equipment of our civilisation. So that metals which were previously unknown or unimportant have now become "key" metals; and new "key" industries have been established, each dependent on some particular items in the natural resources of the earth and therefore on access to the places where those raw materials can be obtained.

The use of tools demands some form of power. The only power at the command of our first primitive ancestors was that of their own muscles. Later came the addition of animal labour for some purposes. This was only available in quantity in those regions in which work-animals could find a sufficiency of food at all seasons; and the particular kind of animal which could be used in large numbers depended on the natural vegetation, and so on the climate

of each region. Oxen are probably the most important work-animals; though in some parts of the world they are supplemented, or even replaced, by horses, mules, camels and elephants.

Civilised man early learned to supplement human and animal labour by using the winds to drive his boats along, and wind or running water in simple mills to grind his corn. In regions where these forms of power are available in abundance, on a scale small enough to be harnessed by the simple machines of the ancient and mediæval worlds, as in north-west Europe, they played a considerable part in the economic and social evolution of human societies.

In the past mechanical power was available only on a small scale; and the great discoveries which ushered in the Modern period, quite comparable in their revolutionary effects to the discoveries of metals which ended the Stone Ages, were those which enabled Man to use mechanical power on a large scale. These have depended mainly on heat engines; and so have given importance to the stores of fossil fuel in our coal-fields. Before the modern age coal had no more than a local value as a fuel; and the distribution of the coal-fields had no influence on human society, and therefore no practical importance. Since then coal has become the chief source of power; and the geographical distribution of the accessible coal deposits has exercised a very great influence on the development of all the civilised world. More recently other sources of power, such as the mineral oils, have come into use; and the great advances in tool-making, which followed the application of mechanical power to the working of iron and steel, have made it possible to use both water-power and wind-power more effectively, and on a larger scale, than before. Up to the present one general effect of the use of mechanical power has been to concentrate the increased populations and wealth which it has made possible into a few small areas of the earth, the chief of which are on the margins of the North Atlantic Ocean in Europe and North America.

The still more scattered distribution of the luxury materials has also been a factor of some importance in the spread of civilisation. The search for pearls, precious stones, and ornamental metals opened up many routes of trade. The demand for spices, for embalming and for the making of incense, compelled the countries of the temperate zone to keep up some contact with the lands to the south of the great deserts, and with the Indies, throughout the Dark Ages. It was a factor in the exchange of knowledge, and so a stimulant to progress. Yet it is safe to assert that luxury materials have been of less importance than those required for food, shelter and toolmaking.

Nowhere in the world can all the varied materials needed for

the maintenance of civilised life, even in its early stages, be found within any one region. But civilisation depends, *inter alia*, on the bringing together of a considerable variety of materials, and therefore on the possession of adequate means of transport. Hence those geographical features which influence the movement of men and of goods about the surface of the earth are among the factors to be taken into account in the study of Man.

Of these factors we may give first place to distance; even though this must always be reckoned with reference to the means of transport available at the time and place. It was simply the great distances between them that prevented close and frequent intercourse between the great civilisations which grew up in the western and eastern coastlands of the Old World, and in India. This paucity of intercourse, aided by their adjustments to differing physical environments, allowed them to develop on somewhat different lines. The importance of mere distance has tended to diminish with every improvement in the means of communication; but none of these improvements do in fact abolish distance, or change the fact that there is normally much more intercourse between near neighbours than between peoples separated by greater distances.

In the evolution and expansion of Western Civilisation within historic time it is common to distinguish three main phases, which are associated with the use of three widening series of waterways. The first was the *Riverine* stage, during which the chief centres were in the great river valleys of the Near East, and the linking of each into a single cultural region depended mainly on the use of the rivers. This transport early spread out on to the sheltered waters of the inland seas; and the riverine stage passed almost imperceptibly into the *Mediterranean*, or thalassic, stage of ancient and mediæval times. During this long period some knowledge of navigation spread to all the marginal seas of the Old World. The next change came abruptly when, within a single generation (*c.* A.D. 1492 to 1523), with the discovery of the New World and of new and better ways to the Indies, Western Civilisation entered upon its *Atlantic* stage.

These developments were based on more efficient use of the waterways; and such movement on the waters, the "mobility of the Shipmen" as it may be called, was one great factor in human development. It is very closely related to many geographical facts, such as the distribution of land and water and the form of the coasts, the character of the winds and currents, the natural resources of the coastlands, and so on, which made navigation more or less difficult in different areas.

Contemporaneously with the mobility of the shipmen on the coastal waters and the great rivers of the Old World there was a parallel development of mobility in the interior, dependent mainly on the use of the horse, but to some extent on other beasts of burden, along caravan routes. This mobility of the Horsemen was limited to the open areas of the land surface. It did not penetrate far into regions of forest or swamp, or among the more rugged mountains. It established a limited small-scale caravan traffic between the more populous regions of settlement and civilisation in the opposite margins of the Continent. It brought the pastoral peoples of the interior into touch with the agricultural peoples of the oases and the coastlands ; and it led to repeated conquests, the rise and fall of empires, and increasing spread of knowledge.

Here again the Modern World is marked off by the results of the application of mechanical power to its tools of transport. It is the World created by the steamship and the railway, aided now by the automobile. Many of the decisive changes are directly due to the introduction of regular and reliable large-scale transport. The shipping and caravans of the ancient world dealt in small cargoes of costly and non-perishable goods,[1] among which articles of luxury were very prominent. The traffic of to-day transports enormous quantities of cheap goods, which include the food supplies of large populations. It has made possible the utilisation of areas which contain only a small range of natural resources ; and it has thus enabled such lands to be brought within the orbit of a worldwide civilisation arising out of the Atlantic stage of Western Civilisation.

But even our present methods of transport are closely dependent on geographical conditions ; and the main routes of movement are still guided and modified by the surface features of the earth. Few or no natural obstacles are now absolute barriers to human movement. Yet the difference between favourable and unfavourable routes is perhaps more important than ever before, because of the greater volume and speed of the movement of men and goods between different regions.

The importance and influence of climate in the development of Man and his societies is undoubtedly great, though difficult to assess. Climate affects mankind indirectly through its effects on vegetation and on other animals. It limits the range of cultivated plants ; and so the kind of agricultural work which may be carried on in the several regions of the earth. But its direct effects are

[1] There was a temporary exception in the corn traffic of Imperial Rome.

those concerning which it is most difficult to obtain exact and reliable knowledge.[1]

Everyone knows by experience something of what is meant by spells of bracing and of enervating weather; and that most of us are more energetic in the former. Similarly there are on the earth regions of bracing and of enervating climate. The hot and wet equatorial regions are generally enervating; and in other parts of the Hot Belt of the earth the wet seasons have the same character. The stimulus of seasonal change appears to be of great value to Man; for where there is no marked seasonal change in either temperature or humidity no native peoples have risen above savagery except under the compulsion of foreign conquerors The early civilisations developed in regions of moderate seasonal change in temperature and marked seasonal rhythm in the supply of water.

In general we regard the climates of the Hot Belt as enervating; and the peoples of those regions are less energetic and enterprising than those of many of the cooler regions. In the temperate zones the regions of cyclonic climate, and therefore of variable weather, are the homes of the more energetic peoples; while the regions of more monotonous weather conditions appear to be less favourable to the development of human energy. Perhaps we could usefully classify climates as enervating, stimulating, or numbing in reference to their direct effects on human beings

The geographical situation of the leading peoples in each of the successive stages of Western Civilisation shows a shift from the regions of easier conditions, in Egypt and Mesopotamia, where Man learned the technique of agriculture As his knowledge and skill grew he was able to overcome the greater difficulties presented in lands of less regular climate and shorter growing seasons, and benefit by their more stimulating climates. So the centres of civilisation moved towards the north-west. And in the modern world it is noteworthy that the principal focal areas are in the region of cool temperate cyclonic climate of north-west Europe, which includes the homelands of the leading peoples. In the other continents it is equally true that the more energetic leading peoples are those dwelling in regions of cyclonic climate; though, except in North America, these are warm temperate rather than cool temperate. The homelands of all the Great Powers of the modern world are in temperate latitudes; and their more populous and important sections are in cyclonic regions. Such facts point to a close re

[1] Studies of these effects have been made by several workers. See for example Ellsworth Huntington's *Civilisation and Climate*, Yale University Press, 1922.

lation between climatic conditions and human development; but there is not yet a sufficient body of exact knowledge to justify precise statement of this relation

In its effects on national character climate may, and does, act indirectly as well as directly. Let us note, as one example, some differences between our neighbours across the Channel in France and the peoples of this island. The climatic differences are small, but important. In France agriculture is, on the whole, a very trustworthy means of livelihood, bad harvests are comparatively rare, and the nation has learned to rely on its own fields. In Britain, which is nearer by its whole length to that centre of atmospheric instability in the North Atlantic which we call the Icelandic Low Pressure Area, the weather is much more variable and agriculture is notoriously much less reliable In south-eastern England wheat-growing may be a "good gamble," with the prospects of a good crop well harvested in three or four years out of five But to the west and north the seasons are less favourable and wheat-growing becomes a "bad gamble." The lesser reliability of agriculture has throughout many centuries compelled the peoples of Great Britain to place relatively greater dependence on other means of gaining a livelihood, such as fishing, commerce and industry. This difference in the balance of resources has given the more stable and conservative sections of the people the greater influence in France, and the more enterprising and adaptable sections a relatively greater influence in Britain. A larger proportion of the British have been ready to leave their homeland and seek fortune or new homes beyond the seas. Hence the British have been a more stimulating, or disturbing, part of the world's population during recent centuries. The relatively greater adaptability of the British has given them a marked advantage in the modern world; though it is yet uncertain whether this may not be counterbalanced by the lesser social stability which is associated with it.

It is clear, from even so rapid a survey as this, that a very large number of geographical factors must be taken into account in the Study of Man, in respect both to the evolution of human societies in the past and to their present-day distribution and development. Man's dependence on these factors is so complete and so close that no adequate plans for the improvement of his societies and their adjustments to the earth can be made without a systematic knowledge of geography. A fuller knowledge of the natural resources of the earth, or of any country, in the widest sense of that term, is a necessary basis for any scientific world- or country-planning as well as for the understanding of its past development.

THE TUNNY, *THUNNUS THYNNUS*, LINNÆUS

An Account of its Distribution and Biology

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THE tunny, *Thunnus thynnus*, L. (Fig 1), is a member of a family of scombriform fishes represented also by the bonitos and albacores. The family contains a number of species all of which are pelagic and many of which are large, but the tunny is the most famous on account of its immense size and the halo of mystery that has shrouded its life history from earliest times.

The fish are well adapted for fast swimming, having perfect streamline forms. Their movable first dorsal, pectoral and pelvic fins fit into grooves so that when depressed they are flush with the body surface. Their bodies are wholly covered with scales which in the shoulder region are very large and thick and form a " corselet." They possess a number of detached finlets or pinnules in the caudal region, so characteristic of fish of the mackerel tribe. They are also characterised by having a unique and complicated subcutaneous vascular blood system (Kishinouye, 1923).

Thunnus thynnus is probably a fish of very wide distribution. It occurs in the Mediterranean and Black Sea and in the eastern Atlantic from the coasts of Morocco in the south to Iceland and the north coast of Norway in the north, and has been reported even from the Murman coast; it is found in the North Sea, the Cattegat and the Baltic, and is seen round the Azores and possibly near the Canary Islands. We shall see later that its distribution in these regions is considerably modified at different times of the year. On the American side of the Atlantic from Cape Hatteras (North Carolina) to Nova Scotia a tunny occurs which is popularly known as the tuna in the south and the horse-mackerel in the more northerly region of its distribution. The identity of this species is still doubtful. In 1875 it was differentiated from the European tunny by Storer under the name *Thunnus secundodorsalis* on the

FIG A Tunny, *Th nnus thynnus*, caught on a l an ne North Sea being haul on bc rd Col E. T. Peel's Yach *St* pt., 1933

basis of the position of the anal fin and the length of the pectoral. Jordan and Evermann (1926), while still provisionally keeping Storer's classification, were doubtful whether the two fish were indeed separate species. It seems most probable that the tunny of the American and European sides of the Atlantic are the same species, but possibly they are sufficiently widely separated geographically to show distinct variations in some characters.

Even more widely separated are the European tunny and the blue-fin tuna which is found on the Pacific coasts of North America; yet Whitehead (1931) can find no grounds for regarding them as separate species. The blue-fin is found along the Pacific coast from Lower California (Mexico) to Oregon.

The distribution of the tunny has even been considered by some to extend to the western Pacific off the coasts of Japan. The common tunny in Japanese waters is now, however, regarded by Kishinouye and Frade (1925 and 1927) as a distinct species, *Thunnus orientalis* (Schlegel), on the basis of certain anatomical differences in the swim-bladder and blood-system. But it is evident that this fish is very closely related to the European tunny.

The tunny is remarkable among fishes for the red colour of its flesh and because it maintains a temperature of its own higher than that of the surrounding water, a fact first demonstrated by Sir Humphry Davy. Hanson (1929), by inserting a thermometer into a hole six inches deep made under the pectoral fin, found that after 12 minutes the temperature was 15·5° C. and that after a further 15 and 40 minutes it had risen to 17° C. and 23° C. respectively. At this time the air temperature was 14° C. and that of the water 12° C. A number of measurements gave 15° to 15·5° C. as the first temperature immediately after death, and it is thus likely that in life the deep body temperature of the tunny is 3 degrees to 3½ degrees above that of the surrounding water. These measurements were made in Norwegian waters, and Hanson made further observations in the Mediterranean on tunny from the Tyrrhenian Sea. In the back muscle under the lateral line the temperature after 15 minutes was found to be 28° C. on one side and 27·3° C. on the other; the surface water temperature at the time was 22·1° to 21·85° C.

The tunny everywhere grows to a large size, but appears to grow larger on the American side of the Atlantic (if it be the same species), where fish up to a weight of 1,000 lb. are not rare and fish of over 1,300 lb. have been recorded. About fifty years ago one is said to have been taken off Rhode Island weighing 1,500 lb.,

which when divided among various hotels fed over 1,000 people (Sella, 1931, p. 61).

When we make a more detailed examination of the distribution of the Atlantic tunny we find that it shows considerable variation with the time of the year.

The tunny occurs in the Mediterranean all the year round and probably in the warmer waters of the Atlantic. But in more northern regions the tunny's occurrence is distinctly seasonal. It has only been found in Norwegian waters and in the North Sea and adjacent regions from July to November The fish appears to leave the Norwegian coast in October when the temperature of the surface water has dropped to 9° C. (Schnakenbeck, 1929). A similar seasonal occurrence is shown by the tunny on the American side of the Atlantic; there they only appear in the northern waters of the Gulf of Maine and coasts of Nova Scotia from July to October, reaching the Nova Scotia coast from Yarmouth to Halifax in July, and entering the colder waters of the Bay of Fundy in August or September (Sella, 1931, p. 51).

This brief outline of the distribution indicates at once that the tunny is a migratory fish, and it is around this migratory habit that interest has centred from classical times.

Before discussing in detail the theories concerning its life history it is necessary to outline briefly the methods and localities of the commercial fisheries for tunny. The tunny is an oily fish very suitable for canning and is caught in enormous numbers at some seasons of the year.

On the European side two chief methods of capture are adopted, namely by hooks and lines, and by means of nets. Recently in Norwegian and Danish waters, and in the Bosphorus, the capture of large fish by harpoons has also been practised.

The tunny is caught on hooks baited with fish or on artificial lures of feathers or maize in most localities in which it can be taken. It is caught in this way in many regions in the western basin of the Mediterranean, at Tarifa just east of the Straits of Gibraltar, along the African coast as far as Tunis and Tripoli, in the Straits of Messina, and off the Languedoc and Provence coasts where it is also taken in a kind of seine net. It is caught with hooks in the Adriatic, the Ægean, the Bosphorus and the Black Sea. In Atlantic waters line fishing is done especially by vessels from Santander and St. Jean de Luz, near San Sebastian, in the Bay of Biscay and from Concarneau. In more northern waters many are caught by hooks by commercial fishermen and by big-game anglers.

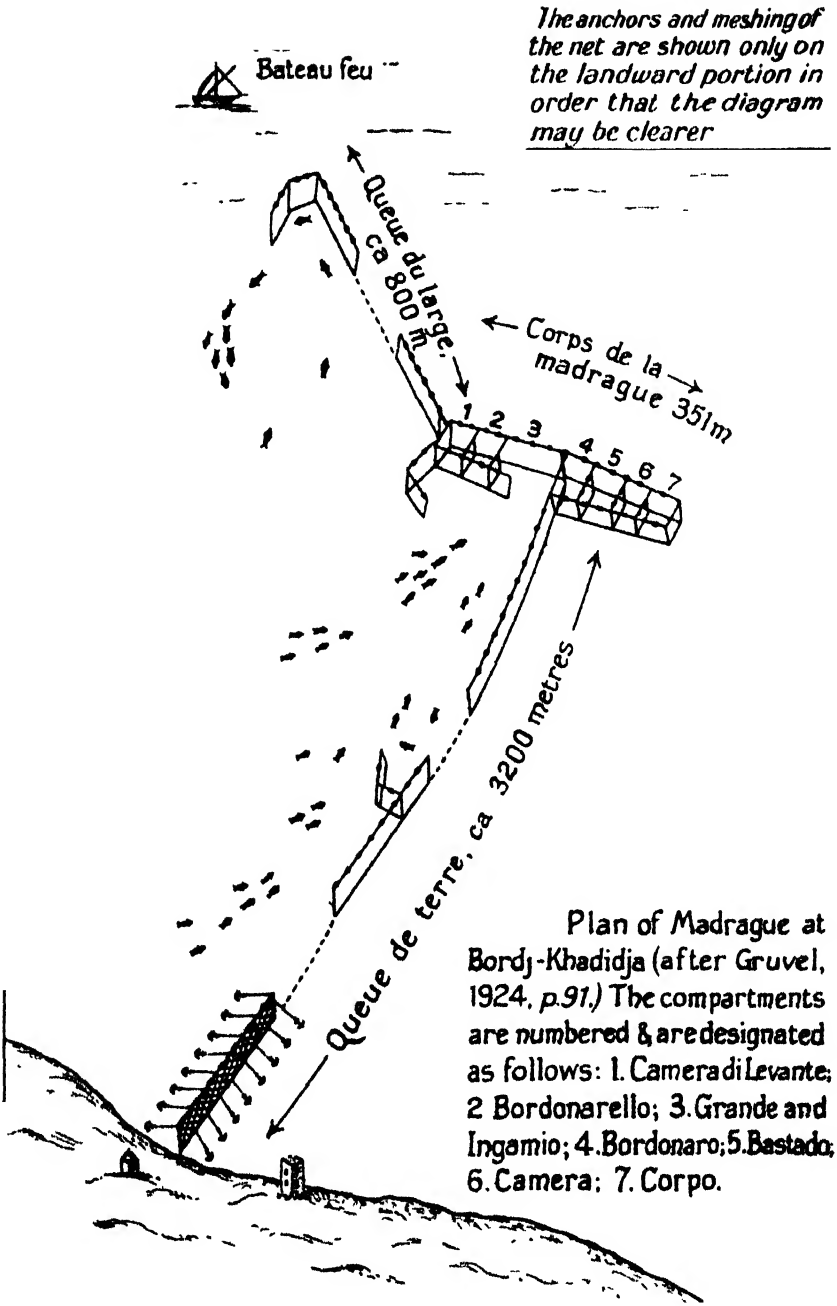
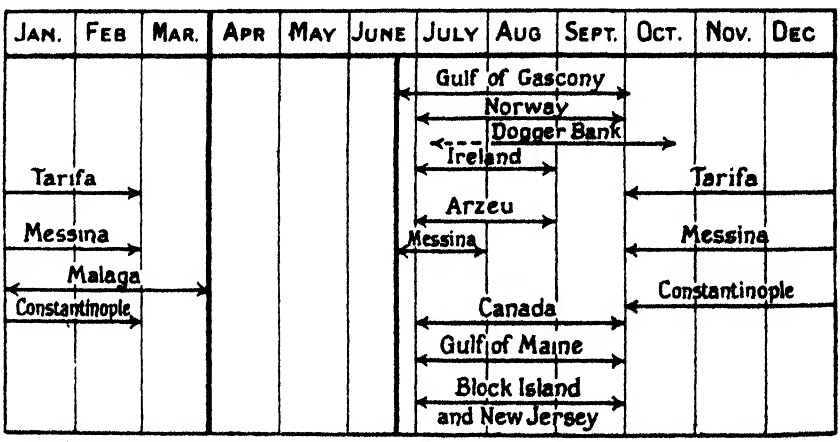

The anchors and meshing of the net are shown only on the landward portion in order that the diagram may be clearer
Bateau feu
Queue du large, ca 800 m.
Corps de la madrague 351m
1 2 3 4 5 6 7
Queue de terre, ca 3200 metres
Plan of Madrague at Bordj-Khadidja (after Gruvel, 1924, p.91.) The compartments are numbered & are designated as follows: 1. Camera di Levante; 2 Bordonarello; 3. Grande and Ingamio; 4. Bordonaro; 5. Bastado; 6. Camera; 7. Corpo.

FIG. 2.

The net fishery in European seas has existed for many years and is based on the habits of the fish. The net generally used is a complicated structure of very large size known as a "madrague" or "thonnaire." It is essentially a system of walls of netting anchored to the sea bottom and so disposed that they divert the tunny into a number of enclosed compartments communicating one with another and leading finally into an end compartment from which the fish are taken (Fig. 2). When this end compartment is deemed sufficiently full its floor is raised to the surface and at an appointed hour the killing takes place. This final transfer of the fish from the nets to boats is known as the "matanza" and is evidently a very stirring spectacle.

The madragues are situated along the coasts in various localities, the majority being in the neighbourhood of Tunis and Tripoli, and of Sardinia and Sicily. There are a few also in the region west of the Straits of Gibraltar on the Spanish and Portuguese coasts and the African coast. The madragues are operated mainly in the period May to July at the time when the tunny are ripening to spawn or have just spawned. At other seasons of the year the hook fisheries are in progress and below is given a table showing the seasons and localities of the main hook fisheries. It is at once evident from this table that the tunny are not taken on a hook during the period April, May and June, just prior to and at the beginning of the time when the madragues are in operation. This is an indication either that the fish have ceased to feed or that they have deserted the localities in which the line fishing is done.

Positions and Dates of Capture of Tunny on Hooks [1]
(After Heldt, *Int. Comm.*, 1931, p. 198.)



[1] The positions of some of the places mentioned are given in Fig. 4.

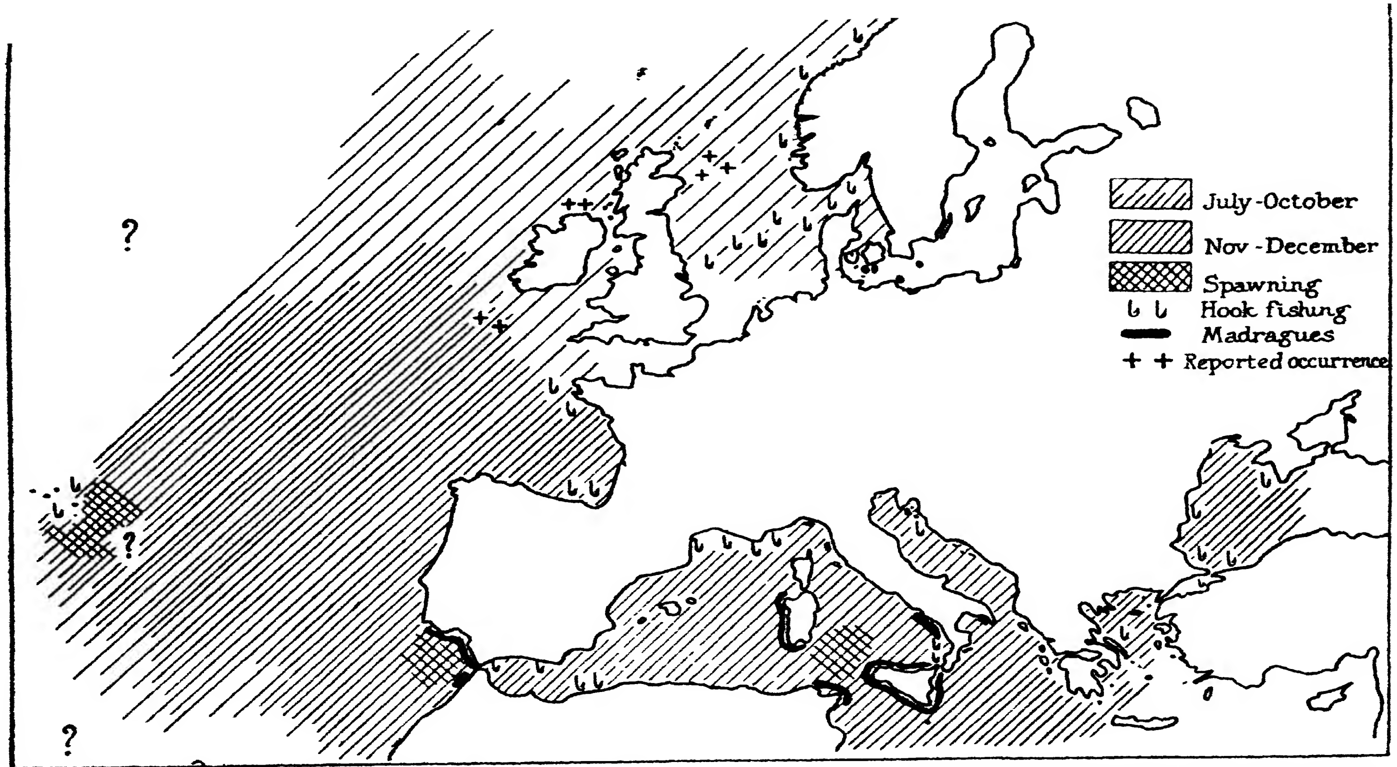


FIG. 3.—Chart showing the distribution of the Tunny, *Thunnus thynnus*, in European waters, and the regions in which hook and line fishing and fishing with madragues is carried out.

Open shading and close shading: probable area of distribution from July to October.
Close shading alone: probable area of distribution in November and December. Cross hatching: probable spawning areas.
Black: localities in which madragues are operated (excluding Tripoli).
Hooks indicate the localities in which hook and line fishing is done. Crosses indicate regions where tunny have been seen but not fished for intensively.

In contrast to this it should be mentioned that in the region of the Azores a certain number of tunny are apparently taken on hooks between April and August. They are also taken in the Bay of Biscay at the same period, but the fish caught are young and immature.

This survey of the main fisheries is a reflection of the habits of the fish. During most months of the year the tunny are dispersed and feeding, but about April there seems to be a tendency for them to collect together and move off in vast shoals to certain regions to spawn during June and July. It is this habit that is taken advantage of by the net fishermen, for the madragues are so situated that they lie across the direct route of some of the migrating shoals. The tunny are thus captured on their way to and from the spawning regions and are known as "Thons d'arrivée" or "de course" and "Thons de retour" respectively, according to whether they are taken before or after spawning. From the above table it can be seen that the hook and line fishing has started again before the end of the main madrague season which extends from April to July. The fish caught on the lines will possibly be those that were the first to spawn.

In Fig. 3 I have given a diagram which shows the main positions of the hook and net fisheries.

It has been known from time immemorial that the tunny is a fish with a marked migratory habit and a classic theory has existed since the time of Aristotle which is still held by some fishermen to-day. The theory was that the tunny were Atlantic Ocean fish which wintered in the Atlantic and in the spring entered the Mediterranean on passage for the Black Sea, where they spawned; after spawning they returned to the ocean.

This theory was modified considerably by the observations of Cetti (1777) and the Duc d'Ossada (1816), who showed that spawning could also occur off the Sardinian and Sicilian coasts, the last named maintaining that the eggs hatched there and gave rise to larvæ which remained in the Mediterranean. Later, Parvesi (1887) considered the tunny as a Mediterranean fish which wintered at great depths and came to the upper layers only to spawn. At the same time Gourret indicated the disappearance of the tunny from the coasts of Provence and Languedoc in the spring and their return in July and August. In 1899 King Carlos de Braganca of Portugal maintained that the Atlantic tunny which go towards the Straits of Gibraltar as though to enter the Mediterranean do not actually pass through the Straits but spawn to the south-east of Algarve and return to the ocean afterwards. These observa-

tions gave rise to the assumption that the Atlantic tunny are a separate race from those of the Mediterranean. It is around this idea that much modern controversy has taken place.

From our knowledge of the seasonal distribution of the tunny, and from the information obtained from the positions and methods of the tunny fisheries on the occurrence of mature fish, it is possible now to state in broad outlines the general life-history of the fish.

The Tunny (*Thunnus thynnus*, L.) is essentially a warm-water fish. It is by nature of a wandering disposition, roaming far and wide in search of its food; the very fact of its beautiful shape and immense strength seems to preclude any possibility of a sedentary habit. It can follow alongside a ship steaming at 8 knots without apparent effort and must in the course of time cover enormous distances. The positions of the madragues and the observations on the state of maturity of the fish show that in May and June there is a concentration for spawning certainly somewhere between Sardinia, Sicily and Tunis, and probably somewhere just west of the Straits of Gibraltar. The disappearance and reappearance of adult fish just before and after the spawning period at many other points along the Mediterranean and Atlantic coasts suggests also that these are the fish that concentrate on the spawning grounds.

After spawning the tunny disperse again over the area of their distribution on a feeding migration. There is a possibility that during the spawning period they have ceased their usual voracious feeding since none are then taken on hook and line except the immature fish. At the time of this feeding migration, probably owing to the warming of the water, the tunny are enabled to extend their distribution considerably into northern waters to regions where abundant fish life is available as food. By the end of June they already appear off the mouth of the English Channel and moving probably mostly up the west coast of Ireland they round the north of Scotland and strike across to the Norwegian coast, some coming southward into the North Sea. In August they are abundant in these regions and may be seen in shoals of twenty or thirty at a time breaking the surface of the water around the trawlers and herring drifters, feeding ravenously on fish escaping from the nets. By October it seems (although it is not certain) that most fish are leaving the now cooling waters and shoals are seen by fishermen on the Grand and Little Sole Banks, south-west of Ireland, in November and December (Le Gall, 1927, p. 320), evidently returning to winter in warmer waters before the reproductive urge calls

them to congregate once more towards their spawning regions in the following spring (see Fig. 3).

Such essentially are the habits of the adult fish in broadest outline; research must, however, be relied upon to fill in much detail. We wish to know how many spawning regions exist and their exact locality, and the conditions that bring the fish to these localities. Above all we wish to know whether the same fish always frequent the same spawning region and whether their offspring do likewise, or whether there is wholesale intermingling of the tunny population. In other words, is the Mediterranean population distinct from that of the Atlantic and can these populations be further subdivided into smaller local populations visiting in the main the same localities from year to year, or is there only one large race of European tunny?

Such problems call for all the technique of modern fishery research and can only be answered by a thorough examination into all stages of the life history of the fish. This implies: (i) the identification and description of the larval and post-larval stages and a searching of the seas for the areas in which they occur; (ii) a study of the subsequent growth of the fish throughout its life; (iii) a system of marking the fish for future identification whereby the movements of individual fish may be studied; and (iv) the search for any characteristics which may show constant variations between fish from different localities.

A good start in these directions has already been made by the notable studies of such workers as Sella, Sanzo, Roule, Heldt and Frade, but insufficient observations have as yet been made to decide the main issues. As a result there are still two main schools; that supported by Roule which favours the idea that, while a certain amount of interchange takes place between Mediterranean and Atlantic, the populations are on the whole distinct and that a detailed study will show certain racial characteristics in structure and habit by which the two main groups may be identified; and the opposing school which receives the backing of Sella and maintains that the Mediterranean and Atlantic tunny are inseparable by any characteristics and that a constant interchange between the populations is taking place.

Summary of Recent Scientific Observations

The eggs of the tunny have been described by Sanzo (1929). They are spherical pelagic eggs 1·0 to 1·12 mm. in diameter containing one large yellow oil globule 0·25 to 0·28 mm. in diameter. The capsule has a fine reticulated structure and the yolk is homo-

geneous. The period of incubation is short and does not exceed two days. The newly hatched larva is 3 mm. in length. For a description of later post-larval stages we must turn to Ehrenbaum (1924) who has described pelagic stages from 4·7 mm to 9·4 mm. in length based on the capture of twelve specimens in the Mediterranean on the cruises of the *Thor*, 1908 to 1910. These young fish were only provisionally ascribed by Ehrenbaum to *Thunnus thynnus* and their identity is still disputed by some (Sella, 1930, p. 453). It is most desirable that the description of these early stages should be settled. Sella (1930, p 453) has reported the capture of many thousands of post-larval tunny in the Straits of Messina, but so far has not given detailed descriptions with drawings for identification, he also records the occurrence of the newly hatched larvæ along the north and eastern coasts of Sicily. De Buen (1924) states that spawning also occurs west of the Straits of Gibraltar, and that the pelagic fry are drifted into the Mediterranean into the large bay between Punta Almina and Cape Tres Forces.

Tunny are caught in small numbers in the region of the Azores between April and August. At the beginning of the season these fish are reported to be ripening and by the end of the season they are spent, during the season fish are also caught with gonads half empty (Ferreira, 1932). This then is possibly an indication that there is a further spawning region somewhere near the Azores. But there has up to now appeared no detailed information as to the locality and abundance of eggs and larval stages in any region and it is time that a detailed search were made for such localities.

The young tunny grow rapidly and those born in June are already 300 to 500 grams in weight by September. The fish are probably mature and ready to spawn in their third year, by which time they have attained a weight of about 15 kg. and are nearly a metre in length.

They are omnivorous fish feeders, preying on the shoals of pelagic fish such as sardines, mackerel and herring, according to the locality in which they are; besides pelagic fish their stomachs have been found to contain gadoids and other fish, also squids and crustacea.

When mature the development of the sexual glands is rapid. It is stated that fish caught during May on the coasts of south-west Spain and in the last week of May off Tunis have small genital glands and that neither eggs nor spermatozoa are yet ripe. In the first days of June a certain number of males are mature but the

females are not fully developed. Towards mid-June the two sexes are fully mature and spawning starts in that month; the majority of fish apparently spawn in the first days of July in Tunis waters, during the first two weeks of that month off Sicily, and during the whole of July on the coasts of south-west Spain for which de Buen gives the following figures:

	♂	♀
May		
Not yet ripe	100%	100%
June		
Not yet ripe	32%	67%
Fully ripe	60%	30%
Spent	8%	3%
July		
Not yet ripe	1%	26%
Fully ripe	33%	12%
Spent	66%	
August (first days)		
Spent .	100%	100%

To supplement this we have observations by Sanzo (Heldt, *Int. Comm. Rep*, 1930, p. 153) who states that during three years he caught in the plankton the first tunny eggs for the season in the Straits of Messina on May 30, May 31 and June 3 respectively, and the last eggs in the last ten days of July.

There is some evidence that the larger fish spawn first and in this connexion it is interesting to note that in Norwegian waters the tunny which arrive first at the beginning of the season are large fish of 200 to 400 kg. in weight, while later in the autumn the majority of fish met with are only 100 to 150 kg. (Sanzo, 1932).

The vertebræ of the tunny show on their centra a number of apparently annual rings, and from the examination of the vertebræ from some 1,500 fish from Tripoli, Sella has given the following figures showing the growth made during each year of life.

Age	Length. (cm)	Weight. (kg.)	Age.	Length (cm)	Weight. (kg.)
1st year .	64	4·4	8th year	182	95
2nd ,,	81 5	9·5	9th ,, . .	195	120
3rd ,, .	97·5	16	10th ,, . .	206	145
4th ,, . .	118	25	11th ,, .	216	170
5th ,,	136	40	12th ,, . .	227	200
6th ,, .	153	58	13th ,, . .	239	235
7th ,, .	169	76	14th ,, . .	254	280–300

It is to Sella that we owe our first exact information on the migration of the tunny. The hooks used by commercial fishermen in different places generally differ in shape and method of attach-

ment to the line sufficiently to make them identifiable ; and Sella conceived the idea of tracing the movements of the fish by the study of hooks that were found in fish that had been lost and caught at some later date. By this means he established definitely that the tunny make considerable migrations and the collection of hooks so obtained has now become one of the first duties of those engaged in research on the tunny.

Sella has thus shown that there is considerable movement among the fish from one part of the Mediterranean to another, and from the Black Sea to the Mediterranean. Furthermore, he has definitely proved that the tunny pass to and fro through the Straits of Gibraltar between the Atlantic and the Mediterranean (Fig. 4) In 1931 he published data giving the number of instances in which movements had been shown as follows :

Between different parts of the Mediterranean	13
Between the Atlantic and the Mediterranean	25
Between the Bay of Biscay and Norway	1

Since then further instances have come to hand, amongst which the capture at Sidi Daoud in Tunis of a tunny carrying in its flesh a harpoon of the type used by Norwegian fishermen is of great interest

Sella has suggested that the tunny may even migrate across the Atlantic Ocean as he has traced a broken hook, found in a fish caught off Sardinia, to a probable American origin (Sella, 1931, p. 67).

Attempts are now being made by various methods to mark tunny systematically, and the Portuguese Government are having many small tunny, captured in the nets, marked with numbered leather collars round their tails, and liberated. It is worthy of mention also that in the summer of 1933 a large number of identifiable hooks were lost in large tunny by big-game anglers fishing in the North Sea (Russell, 1934).

It is largely on the basis of these observations on hooks that Sella maintains his theory that the Mediterranean and Atlantic populations intermingle, and the larger proportion of hooks showing such migration lends considerable support.

It is possible, however, that, while a certain number do intermingle, yet taken as a whole the main populations tend to remain distinct. If this be so, and there is more than one spawning area, it would be probable that some slight and constant variations would be found between fish from different areas, such as is shown by other sea fish like the herring and the cod. A determined effort is being made to look for such characteristics, if they should exist,

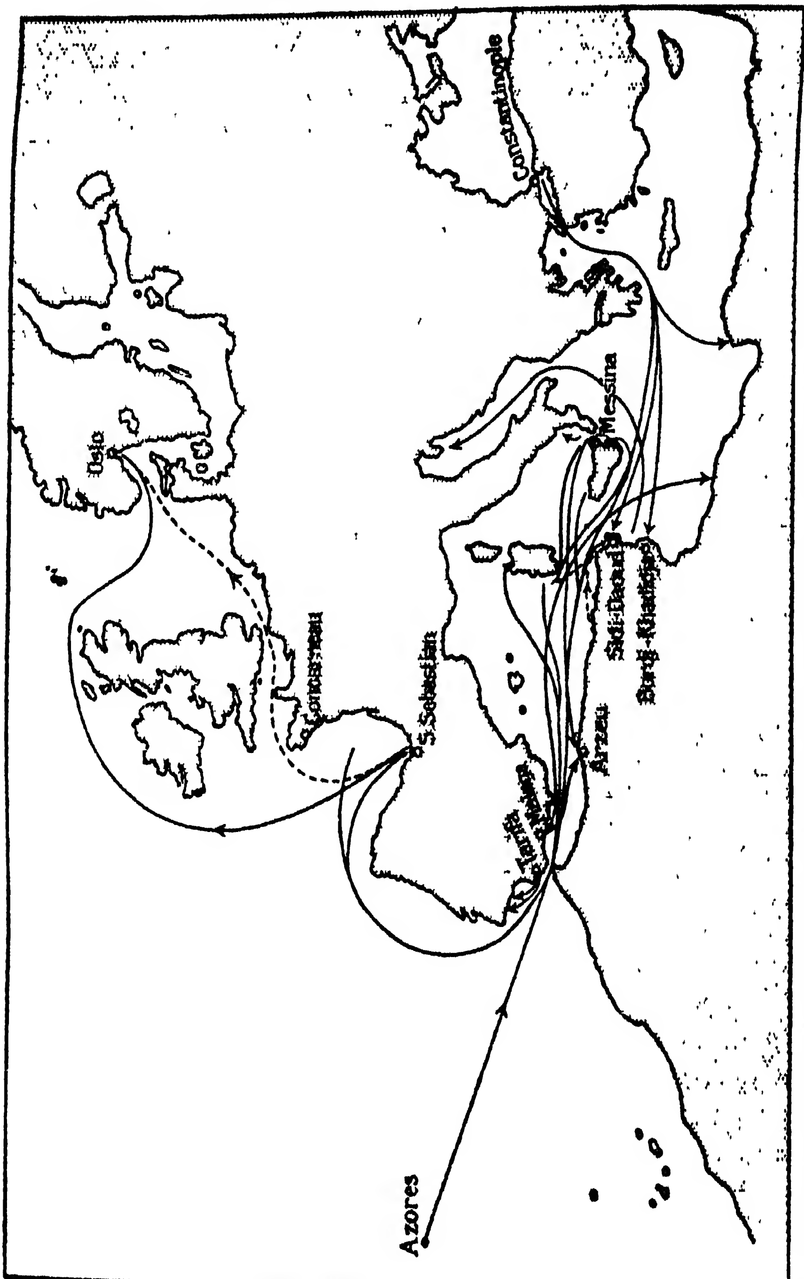


FIG. 4.—Chart showing some of the actual movements made by tunny on the basis of Sella's method of tracing the origin of hooks that have been lost and found in fish caught at a later date.

(*After Heldt*, "*Int. Comm Explor Mediter Rapp Proc Verb*," vol V, 1930, p 160)

and large numbers of body measurements are being made on fish from different localities. Data have so far been published on fish from two localities only, from Tunis on tunny measured by Heldt (1927) and from Algarve, on the Atlantic south coast of Portugal, on fish examined by Frade (1931) While these results appear to show certain differences in body proportions between fish from the two regions the observations are insufficient to be conclusive , they are also further complicated by the fact that certain body proportions change with growth and large numbers of fish of approximately the same size must first be measured. I have myself measured a number of the migrating fish caught in the North Sea and these showed similarities to Tunis fish in some characters, and to Algarve fish in others, while in certain characters they differed from both (Russell, 1934). Whether such differences can really be regarded as significant can only be decided when far more observations have been made In fact, time will show whether indeed biometric data alone can give reliable results Sella maintains that measurements show insufficient differences to justify racial demarcation.

Various theories have been put forward to account for the behaviour of the tunny in relation to the physical and chemical conditions of its environment, but space will not allow a discussion of them In fact, until we have more definite information as to what is the exact behaviour to be accounted for, it seems premature to discuss theoretical suggestions. As with most fish the temperature and salinity of the water are likely to play a large part ; and from the migrations that the tunny makes and from our limited knowledge of its breeding areas it seems that this fish is most sensitive to these conditions around the breeding period, since in its dispersed feeding distribution it must encounter a much wider range of conditions than in the regions in which it spawns. In this connexion a comparison made by Roule (1924) over a number of years of the catches of tunny off Tunis and the rainfall during the periods in which the catches were made are of interest. A definite correlation was found ; the catches being poorest in the years of heaviest rainfall. This probably implied that, just before the breeding period when they are most sensitive to changes in salinity, the tunny which are migrating along the coast swim farther off-shore to avoid the low salinity caused by land drainage than they do in dry seasons. This observation obviously has a practical bearing on the tunny fisheries.

In the list of literature which follows I give only those papers to which actual reference has here been made : full bibliographies

of all literature on the tunny can be found in "A Bibliography of the Tunas" by Genevieve Corwin (1930) and in the many publications by Heldt who, in his reports in the International Commission for the Exploration of the Mediterranean and from the Salammbô Oceanographical Station, brings the literature up to date each year.

REFERENCES

Braganca, D. Carlos de. 1899. "Resultados das Investigacoes scientificas feitas a bordo do yacht *Amelia*," *Pescas Maritimas. I. A pesca do A tun no Algarve em 1898.* Lisbon. (Cited from Roule, 1924.)

Cetti. 1777 "Storia naturale di Sardegna, III," *Gli. Anfibi e Pesci.* Sassari. (Cited from Roule, 1924)

Corwin, Genevieve. 1930. "A Bibliography of the Tunas." *Division of Fish and Game of California, Fish Bulletin No. 22,* pp. 1–103.

De Buen, Odon. 1924. "Les migrations du Thon (*Orcynnus thynnus,* L.) sur les côtes atlantiques du Sud de l'Espagne," *C.R. Acad. Sci. Paris,* T. 178.

d'Ossada, Duc. 1816. *Observations pratiques sur la pêche, la course et les routes des Thons. Messina.*

Ehrenbaum, E. 1924. "Scombriformes" *Rept. Danish Ocean. Exped. 1908–1910,* 2. (Biology) A 11, pp. 12–30.

Ferreira, Ernesto. 1932. "La pesca dell' *Albacora* nelle Azzore," *Note d. Istituto Italo-Germanico di Biologia Marina di Rovigno d'Istria,* No. 1.

Frade, Fernando. 1925. "Sur l'Anatomie de deux poissons Scombériformes : *Thunnus thynnus* (L.) et *Auxis thazard* (Lacép.)," *Bull. Soc. Portugaise Sci. Nat.,* T. X, No. 1, pp. 1–13.

Frade, F. 1927. "Nouvelles recherches sur l'Anatomie du Thon Rouge," *Bull. Soc. Portugaise Sci. Nat.,* T. X, No. 14, pp. 143–9.

1931. "Données Biométriques pour l'Étude du Thon Rouge de l'Algarve (Côte meridionale du Portugal)," *Bull. Soc. Portugaise Sci. Nat.,* T. XI, No. 7, pp. 89–130.

Gruvel, A. 1926. "L'Industrie des Pêches sur les Côtes tunisiennes," *Stat. Océan. Salammbô. Bull. No. 4,* p. 91.

Hanson, Bernhard. 1929. "Beretning om Størjefangsten aarene 1927 og 1928," *Norsk. Fisk.-Tid.,* vol. 48, No. 6, pp. 139–45. (Cited from Schnakenbeck, 1929.)

Heldt, H. 1927. "Contribution à l'Étude des Races de Thons (*Thunnus thynnus,* L.). Caractères Biométriques du Thon Tunisien et Considérations sur sa Croissance." *Stat. Océan. Salammbô. Ann. No. IV,* pp. 1–54.

1926–31. A number of reports in *Rapp. Proc. Verb. Comm. Int. Sci. Explor. Méditerranée.*

1932. "Le Thon Rouge et sa Pêche," *Rapport pour 1931. Stat. Océan Salammbô. Bull. No. 29,* pp. 1–168.

Jordan, David Starr, and Evermann, Barton Warren. 1926. "A Review of the Giant Mackerel-like Fishes, Tunnies, Spearfishes, and Swordfishes," *Occ. Pap. California Acad. Sci.,* vol. XII, pp. 5–113.

Kishinouye, K. 1923. "Contributions to the Comparative Study of the so-called Scombroid Fishes," *Journ. Coll. Agric. Imper. Univ. Tokio,* vol. VIII, pp. 293–475.

Le Gall, J. 1927. "Contribution à l'étude de la Biologie du Thon Rouge (*Thunnus thynnus*, L.). Sur la présence de Thons Rouges en Mer du Nor et dans l'Atlantique Nord-Est." *Cons. Perm. Int. Explor. Mer. Journ. du Cons*, vol. II, No 3, pp. 309-31.

Parvesi, Pietro. 1887 "Le migrazioné del tonno." *Rend. Ist. Lombardo*, Ser. 2, vol. XX, pp. 311 24. (Cited from Roule, 1924.)

Roule, Louis. 1924. "Étude sur les déplacements et la pêche du thon (*Orcynnus thynnus*, L) en Tunisie et dans la Méditerranée occidentale," *Bull. Stat. Océan Salammbô*, No. 2, pp. 1–39.

Russell, F. S. 1934 "Tunny Investigations made in the North Sea on Col. E. T Peel's Yacht *St. George*, Summer, 1933. Part I. Biometric Data." *Journ Mar Biol Assoc*, *N.S*, vol XIX. (*In Press.*)

Sanzo, Luigi 1929. "Nova e larve di tonno, *Orcynnus thynnus*," *Rend. Accad. Lincei* (*Sci. Fis*), vol. IX, pp. 816–20.

1932 "Nova e primi stadi larvali di Tonno (*Orcynnus thynnus*, Ltkn)," *R Comit. Talass Ital. Mem. CLXXXIX*, pp. 1–16.

Schnakenbeck, W. 1929 (i). "Ueber die Bluttemperatur der Thunfische." *Fischerbote*, vol XXI, Heft 19, p. 307.

1929 (ii) "Ueber Thunfischfange in nordischen Gewassern," *Fischerbote*, vol XXI, Heft 22, pp. 348-51.

Sella, Massimo. 1930. "Distribution and Migrations of the Tuna (*Thunnus thynnus*, L) studied by the method of hooks and other observations," *Int. Rev. d. ges Hydrogr. u. Hydrobiol.*, Bd. 24, pp. 446–66.

1931 "The Tuna (*Thunnus thynnus*, L.) of the Western Atlantic. An appeal to Fishermen for the Collection of Hooks found in Tuna Fish," *Int Rev d. ges. Hydrogr. u Hydrobiol*, Bd. 25, pp. 46–67.

Whitehead, S S 1931 "Fishing Methods for the Bluefin Tuna (*Thunnus thynnus*) and an Analysis of the Catches" *Division of Fish and Game of California, Fish Bulletin No. 33*, pp 1–34.

PHOTOELECTRIC CELLS

By D H FOLLETT, M A, A Inst P

A FEW years ago, the demands of the newly developed talking-picture branch of the cinema industry began to stimulate research in devices which would give an electric response to light. It was necessary that the electric response should reach its final value practically instantaneously, and this consideration immediately precluded work on such energy-sensitive devices as the thermopile. There were at that time two light-sensitive devices which had been in use for photometric purposes in scientific laboratories for some time. One type was called the "photoelectric cell," the other the "selenium cell." The latter had found some commercial application already, but it suffered from the same defect as the energy-sensitive devices mentioned above, though not to such an extent as to make it completely unsuitable for cinema purposes It was much more sensitive to light than the photoelectric cell, and this was probably responsible for its continued development. However, work was mainly concentrated on the photoelectric cell, which as a result has now developed into a common commercial article finding numerous applications in industry. Incidentally, the knowledge gained in the course of this development has allowed the production of cells which for laboratory purposes are tremendous improvements on the old type. Whereas it previously needed a skilled experimenter to obtain good results with photoelectric cells, they are now incorporated in scientific instruments which can be reliably used by experimenters who have no particular knowledge of electricity.

This pronounced interest in light-sensitive devices has resulted in the production of other types besides the original ones, as is not surprising. One of these appears already to have died out, but the other promises to become very important in the laboratory. The existence of different types and the widespread interest in them has led to a certain confusion in nomenclature for referring to them : there is as yet no definitely recognised system. The general practice now is to refer to all devices which produce an electric response to light as "photoelectric cells," whereas the term was previously

limited to one type, as mentioned above. Etymologically this present practice seems justified. To distinguish the different types we will adopt here the nomenclature used by Campbell in a recent paper [1] on photoelectric cells.

Light-sensitive devices fall into four classes which exhibit their electrical response in different ways. It is probable that in all cases the primary result of illumination is the production of the well-known "photoelectric effect," which has been of such tremendous importance in the development of modern physical theory A brief exposition of the photoelectric effect will not therefore be out of place.

It was discovered by Hertz when he was working on the experimental verification of Maxwell's electromagnetic theory. He had in his apparatus two sparks, working in independent circuits, and one of his operations consisted in adjusting the length of one of the spark gaps until he found the maximum length which a spark would jump across. Results obtained at different times were inconsistent and he found ultimately that the maximum length of the gap depended upon whether the electrodes were illuminated with light from the other spark or not. He recorded this fact in a paper [2]; then he continued his electromagnetic experiments and proved Maxwell's theory up to the hilt. Other workers took up the study of the phenomenon which he had recorded and their results turned out later to be of paramount importance in the development of the quantum theory, which, as is well known, seemed quite irreconcilable with the electromagnetic theory which Hertz had experimentally proved. After more than forty years the reconciliation of the two theories is still not finally attained. It is a curious turn of fortune that an accidental discovery in the course of experiments which apparently proved the validity of the one theory should provide the foundations of the other

The effect which Hertz had accidentally stumbled upon was that when a metal is illuminated by light of suitable wavelengths electrons are emitted from it. It was found that a metal gives this effect in response to all light whose wavelength is shorter than a certain critical value characteristic of the metal and referred to as the "threshold." In Hertz's experiment the metal of the spark gap was such that the ultra-violet light from the other spark was the exciting radiation, but it was found that the effect is not confined to ultra-violet light and that some of the alkali metals are sensitive to visible light. Further, instead of the sensitivity steadily increasing as the wavelength decreased, as is the case for most metals, for these alkali metals there is a peak in the curve connecting sensi-

tivity and wavelength. This is usually known as the "selective" effect, and there are certain differences in detail between the effect in these "selective" regions and in the general case; these differences are of little importance in practice, but are very interesting to the theoretical physicist

The threshold wavelength increases as we pass along a group in the Periodic Table. To take the alkali metals as an example, lithium at one end of the group is insensitive to wavelengths longer than about 3,600 Ångstroms, which is in the ultra-violet, while cæsium at the other end is sensitive to all the visible wavelengths except the extreme red.

The mechanism of photoelectric emission is important, as it indicates why there is an upper limit to the wavelengths to which a surface is sensitive. From the point of view of the photoelectric effect, radiation acts as if it were concentrated in packets, and not spread out uniformly over a wave-front as the wave theory supposes, and each packet appears to have an energy which is proportional to the inverse of the wavelength of the radiation as given by the wave theory. (This is a curious mixture of the corpuscular theory with the wave theory.) When one of these packets strikes an electron in the sensitive surface, it imparts its energy to that electron. This electron then leaves the surface if the kinetic energy it has acquired is sufficient to enable it to break away from the attraction of the atoms surrounding it. It will then emerge with a velocity given by the equation $\frac{1}{2} mv^2 = \frac{hc}{\lambda} - P$ where m is its mass, v its emergent velocity, h, c are constants, λ the wavelength of the light which excited it, P is the work done in breaking away from the surface. From the equation it is obvious that if $\frac{hc}{\lambda}$ is less than P then the electron will not escape. P is different for different metals, and also varies according to the state of the surface, as is only to be expected. A particular surface will therefore be sensitive to light of wavelength λ only if $\frac{hc}{\lambda}$ is greater than a certain value characteristic of that surface; that is, if λ is less than a certain value, which is the "threshold" mentioned previously.

Different Types of Cells

The type which appears at the moment to be of the least importance depends on the so-called Becquerel effect, discovered as long ago as 1839 [3], which is that in certain solutions a voltage is produced at an electrode of suitable composition on illumination of that

electrode. A photoelectric device based on this effect was introduced two or three years ago in America, but little has been heard of it since. Nothing more need therefore be said about this type.

The selenium cell is the best known of the next type, which Campbell refers to as "conductive." The action depends on the fact that certain substances, which are poor conductors of electricity, alter their resistance when illuminated. The effect was discovered in selenium in 1873. It is made use of by mounting the substance between electrodes and connecting a battery across them. A small current flows, and if the amount of light falling on the cell alters the current also alters as a result of the change of resistance. Unfortunately, the change is not instantaneous, and also the cell does not recover fully from any change in conditions for quite a long period; in the case of some cells this period is one of days. Where high intensities are employed this effect is relatively small, but for scientific measurements where low intensities are used the effect is serious, and very carefully designed methods have to be adopted to overcome the difficulty. In the case of selenium the change in resistance is proportional very approximately to the square root of the intensity of the light; the device is thus relatively less sensitive to high intensities than to low intensities, to which it is very much more sensitive than any other cell. This high sensitivity makes it very attractive at first sight, but the difficulties compared with those encountered with other types of cell are so great that it is rarely used now for scientific measurements of intensity. The foregoing objections do not apply to its application to cinema work, where comparatively high intensities are used, but the drawback to its use here is that its response is not instantaneous. The effect of this is that distortion of the sound is produced, the high frequencies being suppressed with respect to the low frequencies. But by suitably designing the amplifier so that the higher frequencies are more amplified than the lower, this effect can be compensated for. The type of cell more usually used needs only a straightforward amplifier, and thus the selenium cell stands little chance of adoption for this work in spite of its greater sensitivity. Its use is therefore restricted to those applications where it is only required to detect the presence or absence of a light beam, as in the now well-known burglar alarm in which a beam of light is directed on to a photoelectric cell, the interruption of this beam causing an alarm to operate.

Other substances besides selenium are used in cells of this type; the most noteworthy example is the "thalofide" cell developed in America [4]. The sensitive substance here is a compound of thallium, oxygen and sulphur.

The theory of this effect has been neglected until the past few years; attention has been directed far more to its application to commercial purposes. But Gudden and Pohl in a long series of researches beginning about 1921 and published in a number of papers in the *Zeitschrift für Physik* in succeeding years, have proved that in photo-conductive materials the primary effect of illumination is the liberation of electrons within the body of the material, and that secondary effects which tend to mask the primary effect are set up by the passage of the primary current [5] In selenium the secondary current is so much larger than the primary that the latter is completely obscured. Since selenium is the best-known photo-conductive material it is not surprising that a clear theory of the photo-conductive effect, showing its relation to the simple photoelectric effect, has not been derived earlier.

The third type is of growing importance. Campbell refers to it as the "rectifier" type. It was discovered as recently as 1927 out of an observation by Grondahl [6] that copper oxide rectifiers used for the conversion of alternating currents to direct were affected by light. The first photoelectric device based on this discovery was described by Lange [7]. His cell consisted of a thin layer of cuprous oxide deposited on a copper plate which formed one electrode, with a very thin semi-transparent metal film deposited on the oxide to form the other electrode. Fig. 1 shows the direction in which the current flows when the upper surface is illuminated. No battery is required to drive this current. The interesting point about this is that the direction of the current is opposite to that in which the cell, which acts as a rectifier, will allow a current to flow when a potential is applied to it. The sensitivity of the Lange cell extends far into the infra-red (to 66,000 Ångstroms) and it has a maximum sensitivity to light of wavelength 8,000 Ångstroms, the extreme limit of the visible spectrum. By certain modifications in methods of manufacture cells can be made which are sensitive only to visible light.

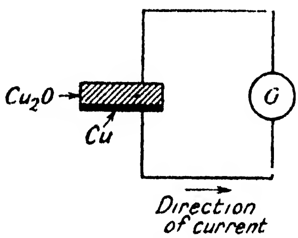


Fig. 1.

At first sight it would seem that the primary effect of illumination is to cause the generation of an E.M.F. as in the case of the thermocouple, but it has been definitely proved by Auwers and Kerschbaum [8], from a consideration of the characteristics of the cell on open circuit and when short-circuited, that the primary effect is the generation of a current. This current is proportional to the

intensity of the light falling on the cell if the external resistance through which it flows is small.

Other more recently developed cells of this type employ selenium. In general they have a higher sensitivity than the copper oxide type. In response to light from a tungsten filament gas-filled lamp 300 microamperes per lumen has been claimed for them, as against 100 microamperes per lumen as the biggest claim for the copper oxide type; commercial types of both kinds are usually well below this standard, however (though there is one very recently developed type which attains the higher figure). Here again the current is proportional to the intensity of the light exciting it if the external resistance is small compared with that of the cell [9]

The use of cells of this type is practically confined to the laboratory. They cannot be used for cinema work as their output is too small to be usable without amplification; they cannot be coupled satisfactorily to an amplifier, and this rules them out apart from any other considerations. Insufficient is known yet for them to be used for precision work in photometry, but they are already in use where the greatest accuracy is not required.

The fourth type is by far the most widely used nowadays and is the one used in the cinema industry. It is referred to by Campbell as the "emission" type It developed directly out of the discovery of the photoelectric effect by Hertz, and was not accidentally discovered ready made, as the other types were. We will treat this type more fully than the others. in the first place it is the most important, and in the second place it is a logical combination of previously known phenomena and therefore is of greater general scientific interest than the other empirically developed types.

It consists of a glass bulb, in which is deposited a surface of the photoelectrically sensitive metal, either on a conducting surface previously deposited on the wall, or on a metal plate mounted inside. Also, a metal wire, which can take any convenient shape, is sealed into the bulb and insulated from the sensitive surface. In the simplest form the bulb is completely evacuated. Leads are taken from these two conductors and connected to a battery so that the metal surface is at a negative potential with respect to the wire. When the surface is illuminated electrons are emitted and these are carried over to the wire by the electric force existing between it and the surface. The photoelectric surface and the wire therefore act as cathode and anode respectively. A current flows in the circuit and can be measured by any suitable measuring instrument connected in it.

Fig. 2 shows diagrammatically the shape of a typical modern cell. Practically the whole of the inside of the bulb is silvered for the deposition of the photoelectric substance, part being left clear for the admission of the light, though the representation of this has been left out for the sake of clearness. The valve cap is cemented to the bulb in order to provide a suitable means of mounting the cell and the connection to one of the electrodes is taken to one of the pins. The terminal shown at the top provides the connection to the other electrode.

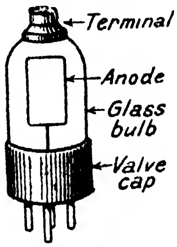


Fig. 2.

The number of electrons emitted by the sensitive surface is proportional to the intensity of the light falling on it. The current will also be proportional to the intensity of the light if all the electrons are carried over to the anode. This occurs only if the voltage exceeds a certain value which depends upon the shape of the bulb and the electrodes, and it is clear that any further increase in voltage cannot produce an increase in current. This limiting voltage lies between about 10 volts and 50 volts in most of the cells at present on the market If the bulb is filled with gas at a low pressure, however, the current continues to increase as the voltage

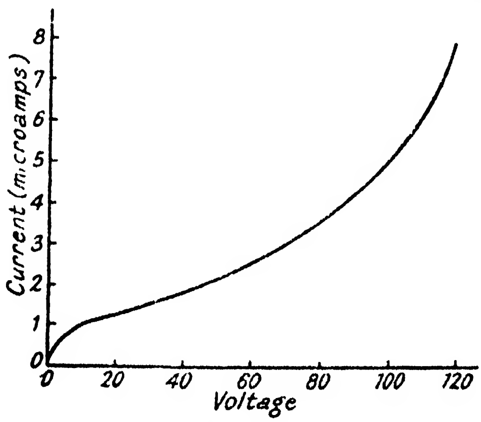


Fig. 3.

increases. The relation between current and voltage for a typical cell is shown in Fig. 3. When the voltage reaches a certain value, which depends on the geometry of the bulb and electrodes, the pressure and nature of the gas, and the intensity of the light, a glow appears in the bulb. When this stage is reached the current is independent of the light, but until then the current remains approximately, but not exactly, proportional to the intensity. A much

greater current is usefully obtainable, therefore, than from an evacuated cell. But certain disadvantages accompany this increased sensitivity : the exact proportionality between current and intensity is lost, but this is only occasionally a disadvantage ; the response of the cell to a sudden illumination is not absolutely instantaneous ; and the cell becomes liable to slight irregularities in behaviour.

The effect upon which this magnification depends is known as "ionisation by collision." If an electron in passing across from the cathode attains more than a certain minimum velocity it may, on collision with a gas molecule, eject an electron from that molecule, thus forming a positive ion. Where there was formerly one unit charge of electricity, there are now three and these are all free to be collected by the electrodes so that the current is increased by an amount corresponding to two extra charges of electricity. If the voltage is high enough, either of the electrons or the positive ion may obtain sufficient speed in their journey to the electrodes to ionise another molecule, so that the current is still further augmented.

The higher the voltage between the electrodes, the greater will be the velocity which the electrons will attain, and the greater the amount of this ionisation Thus as the voltage increases the current increases. The inert gases are usually used for filling photocells, and for these the effect starts when the voltage between the electrodes reaches about 18 volts The curve in Fig 3 was obtained with a modern cell, sensitive throughout the visible spectrum but not to longer waves, illuminated by a 60-watt lighting lamp 8 inches away from it.

There is another effect by which an increase in sensitivity is obtained when potassium, thickly deposited, is used as the photoelectrically sensitive substance. It is achieved by filling the cell with hydrogen at a particular pressure and passing a glow discharge for a certain time, the cell afterwards being refilled with hydrogen at a low pressure. In this process the appearance of the sensitive surface undergoes a change ; this is an indication of the importance of the state of the surface

Cells using one or other of the alkali metals more or less thickly deposited and "sensitised" as above, were used in the laboratory, chiefly for photometric purposes, from 1892, when Elster and Geitel made the first photoelectric photometer [10]. The metal used, of course, would depend upon the spectral range of the light with which the cell was to be used. As these thickly deposited alkali metal cells are now practically obsolete, no more need be said about them. The only one still regularly used is sodium, which is sensitive in the

ultra-violet; although other cathodes are available, sodium is still the most generally used for ultra-violet work.

For cinema work all that is required is that the cell should instantaneously give as large a current as possible in response to white light from a source such as the tungsten filament gas-filled lamp; it is immaterial what the spectral range of sensitivity is. Of the thickly deposited alkali metals, potassium is the most sensitive. Without gas filling, a cell with a sensitive area of one square inch will give a current of only about one-hundredth of a micro-ampere per foot candle, for a light source consisting of an ordinary lighting lamp: for a gas-filled cell the current can be about ten times greater and more under certain conditions; the amount depends upon the intensity of the light. This is very small, and the first object of research in the production of photoelectric cells for cinema purposes was to obtain greater sensitivity.

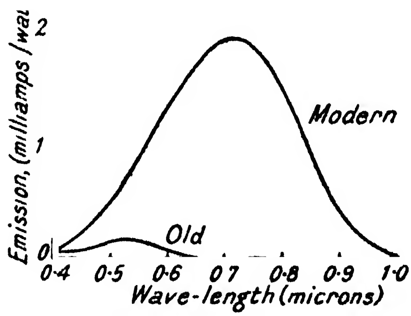


FIG. 4.

The cell which developed for cinema work from this research has a cæsium cathode. In the original form of cæsium cell the metal was deposited in a layer of considerable thickness, usually on a silver surface which had been previously deposited chemically on the glass wall of the bulb. The increased sensitivity of the modern form depends on the preparation of this surface before the cæsium is deposited, and on the fact that the cæsium is deposited as a very thin film [11]. The effect of this is to increase the range of wave-lengths to which the surface is sensitive; the increase is at the long-wave end of the range. The curves in Fig. 4 illustrate the differences in sensitivity between the two types. It will be seen that the original cæsium cathode was insensitive beyond about the middle of the red part of the spectrum (wavelength about $\cdot 65\mu$), but the modern one is sensitive in the infra-red, the limit actually being about $1\cdot 2\mu$ though the response is too small beyond about 1μ to

be appreciable in the figure. An ordinary electric lamp radiates very much more energy in the spectral region between $\cdot 65\mu$ and $1{\cdot}2\mu$ than in the region up to $\cdot 65\mu$ so that a very much bigger proportion of the total energy radiated by the lamp is now available for causing the emission of electrons. It is largely to this effect that this cell owes its great sensitivity to white light, and not just to an intensification of the effect over the same region as it was sensitive to in its old form. The number of electrons emitted for a given illumination in the present form of cæsium cell is about twenty times that in the old potassium form which was previously the most generally used with white light sources. Great progress has therefore been made. Different makers put forward different claims for the sensitivity of their products, but this seems to be a fair average figure

Potassium has been deposited in a similar way, with a similar effect on its properties. It is sensitive throughout the visible spectrum in this form, instead of just as far as the green as in its old form, but its sensitivity to white light is very little greater, as its actual response at any particular wavelength is comparatively small. Its field of application is photometry, as it is sensitive over the whole of the visible range of wavelengths.

Cathodes consisting of other metals, deposited by special processes, have also been produced, chiefly in America, but they are mostly of theoretical rather than practical interest. One of the three cathodes mentioned—cæsium and potassium in the form just described, or sodium in the original form—will suffice for most purposes. An exception is where photoelectric cells are used to measure the intensity of ultra-violet sources for therapeutic purposes. It is necessary that the cells should be sensitive only to those rays which have a therapeutic value, and for this purpose uranium [12] and cadmium [13] have been used.

In general, of the three different kinds of photoelectric cell now available the "emission" type is quite the most useful. In one of its forms it can be applied in any field where a light-sensitive device is required, although the use of one of the other types is in special cases a little easier. For example, for the photometry of lamps the "rectifier" type is very suitable, as only a galvanometer is needed to complete the apparatus. In the well-known application to burglar alarms the "conductive" type is most simply used owing to its high sensitivity. But the "emission" cell can be used for such purposes quite easily. For almost all precise scientific work it is the only type which can be used and where very low light intensities, such as are met with in spectrophotometry, have to be dealt with, neither of the other types is applicable.

REFERENCES

1. Campbell, *Rev. Sci. Inst.*, **9**, 369, 1932.
2. Hertz, *Ann der Phys.*, **31**, 983, 1887.
3. Becquerel, *Comptes Rend*, **9**, 144, 1839.
4. Case, *Phys. Rev.*, **15**, 290, 1917
5. A formal account of the theory is given by Gudden and Pohl in *Zeits. f. Phys.*, **37**, 881, 1926.
6. Grondahl, *Science*, **36**, 306, 1926, and *Journ. Amer Inst. Elec. Eng.*, **46**, 215, 1927.
7. Lange, *Phys. Zeit.*, **31**, 139, 1930, and **31**, 964, 1930.
8. Auwers and Kerschbaum, *Ann der Phys*, **7**, 129, 1930
9. Very few details are available concerning the methods of making these "rectifier" cells. The reasons for this are probably commercial.
10. Elster and Geitel, *Ann. der Phys*, **48**, 338, 1892, and **48**, 625, 1892.
11. Koller, *Journ. Opt. Soc Amer.*, **19**, 135, 1929.
12. Rentschler, *Journ. Amer Inst Elec. Eng*, **49**, 113, 1930.
13. Taylor, *Journ. Opt. Soc Amer*, **23**, 60, 1933

RECENT ADVANCES IN SCIENCE

APPLIED MATHEMATICS. By Professor F. E. Relton, D.Sc., M.A., Royal School of Engineering, Giza.

Mechanics.—On two previous occasions in this journal (No. 106, Oct 1932; No. 108, April 1933) I have mentioned the work of A. Krylov on the secular equation for small oscillations, together with N Luzin's examination of the underlying theory The work has now progressed a stage further and may be considered practically complete. Taking, as usual, q_i as a generalised co-ordinate, and generically a_{rs} as the coefficients which occur, the periods of small oscillation are usually found from a determinantal equation in λ. This may be succinctly written as

$$| a_{rs} - \delta_s^r \lambda | = 0 \quad . \quad . \quad . \quad . \quad (1)$$

where δ_s^r is Kronecker's delta.

When the number of degrees of freedom exceeds about five, the numerical work involved in the actual computation of the periods tends to be very laborious The solution of the developed equation, by Graeffe's squaring method, is itself a matter of hours' work, but the real labour is in developing the determinant. At various times, different methods have been proposed by Lagrange, Laplace, Jacobi and Leverrier, and of these Leverrier's is perhaps the most practical, with Jacobi's taking second place, but all are somewhat tedious.

The trouble arises through λ occurring down the diagonal. There would obviously be a saving of labour if one could devise a means of keeping λ in the first column. This, in fact, is what Krylov has done, and the method is known as Krylov's Transferring Multiplier. He starts with an auxiliary group of equations which we may write generically as

$$D^r x = x^{(r)} = a_r q_1 + b_r q_2 + \dots + f_r q_k \quad . \quad . \quad . \quad (2)$$

If the q's be eliminated from these k equations, we get, in determinantal form, a linear differential equation, of order k. Its development can be written

$$Mx^{(k)} - M_1 x^{(k-1)} + \dots + (-)^k M_k x = 0 \quad . \quad . \quad (3)$$

where the M's are the respective minors.

If the a_{ij} matrix be p-times repeated, we can write its elements as a_{ij}^p. Krylov then gives the following rule for the determination of $a_r \ . \ . \ . \ f_r$:—For $r = 0$ they are arbitrary ; the others are linear combinations of these. Thus

$$c_p = a_{13}{}^p a + a_{23}{}^p b + \qquad + a_{k3}{}^p f.$$

It can be shown that (3) is equivalent to (1), so that $Mx|a_{rs} - \delta_s{}^r\lambda|$ is equal to the eliminant of (2) This M is Krylov's Transferring Multiplier.

As previously mentioned, Luzin's first commentary was admittedly incomplete. He has since continued the investigation, and his results are embodied in three Russian papers, "Sur certaines propriétés du multiplicateur inversant dans le procédé de Mr. A. Krylov," *Bull. Acad. Sci. U.R.S.S.*, VII, **5** (595–638) ; **6** (735–762) ; **8** (1065-1102). Starting from two arbitrary matrices, $A = (a_{ik})$, $B = (b_{ik})$ with $|B| \neq 0$, let $A^* = B^{-1}AB$ and let M, M^* be Krylov's Transferring Multiplier for A, A* respectively It can then be shown that $M^* = |B| \cdot M$ and that M is the product of k linear forms, none of which can vanish identically. These linear forms are all real if the roots of the secular equation in λ are real. Moreover, if in Krylov's transformed equation we replace $x^{(p)}$ by λ^p, the roots of the resulting algebraical equation are the roots of the secular equation. Luzin analyses the case where the transformed determinant vanishes identically, a case for which Krylov himself gave a special rule. The later part of the work is concerned with geometrical interpretations. The arbitrary $(a, \ . \ . \ . \ f)$ can be regarded as the co-ordinates of a point in a k-dimensional Euclidean manifold, and use is made of manifolds which are linear transforms of each other.

NUMERICAL.—The number of formulæ extant for numerical integration is pretty considerable, so much so that it is not always easy to decide which is the best for any particular piece of work. The approximate formulæ can usually be classed as particular cases of general theorems. Thus Weddle's seven ordinate rule comes under Gregory's formula ; the mid-ordinate rule, three-eighths and Simpson's rule come under the Newton-Cotes formula, to which Gauss's formula is closely related. All these have their foundations in the calculus of finite differences.

In contrast with these, and standing out by its strongly marked individuality, is the formula of Tchebycheff, first published in *Liouville* (2) **19,** 1874 and included in his *Œuvres*, **2,** 163. It resembles Gauss's formula in that the ordinates are not necessarily taken at equal intervals ; but its outstanding

characteristic is that the coefficients are all equal. His general formula is

$$\int_{-1}^{1} f(x)dx = \frac{2}{n}\Sigma_1{}^n f(x_r).$$

It is based on the assumption of $f(x)$ being such that its $(n + 1)$th differences are negligible. The x_r are determined by equating to zero the polynomial part of

$$x^n \exp\left(-\frac{n}{2.3x^2} - \frac{n}{4.5x^4} - \ldots\right)$$

The matter has recently received attention from S Bernstein. Writing in Russian on "Tchebycheff's Formula for Approximate Quadrature," in *Bull. Acad. Sci. U.R.S.S.*, VII, **9**, he considers the formula

$$\int^{1} f(x)dx = \frac{1}{n}\Sigma_1{}^n f(x_i).$$

The x_i are to be chosen so that the formula is exact for an arbitrary polynomial of degree n; but for general use, it is essential that all the values of x_i shall lie in the range 0, 1. This is known not to be the case for all values of n, e.g. $n = 8$.

A question now intrudes itself. Is there a lower bound to n, above which it inevitably happens that some of the x_i lie outside the range? If the answer is in the affirmative, we are faced with the curious phenomenon of an approximation rule which fails to work if too many data are supplied. It would be useless attempting to improve the accuracy of the approximation by taking ordinates of number exceeding the lower bound.

The result of Bernstein's work is to show that such a lower bound exists. His argument, *reductio ad absurdum*, is based on the fact that $\phi(a) = an + 0(\sqrt{n})$ where $\phi(a)$ is the number of roots x_i such that $0 < x_i < a$. It then becomes possible to construct polynomials, of sufficiently large degree n, for which Tchebycheff's formula is not exact. There is consolation in knowing that, as regards the lower bound N, there are indications that $N < 15{,}000$.

HYDRODYNAMICS.—The researches of Leon Lichtenstein, on the equilibrium configuration of rotating masses of fluid, now extend in time over something like fifteen years. His earlier work, in which he developed a general theory of the homogeneous figure of equilibrium, is to be found in *Math. Z.*, **1** (1918), **3** (1919), **7** (1920). His more recent work, on the heterogeneous fluid, is embodied in a long paper, "Untersuchungen über die Gleichgewichtsfiguren

rotierender Flüssigkeiten, deren Teilchen einander nach dem Newtonschen Gesetze anziehen. III Abh. Nichthomogene Flüssigkeiten. Figur der Erde," *Math. Z.*, **36**, 481–562 (1933).

The method which had been developed previously is here applied to the case where neither the initial configuration nor the derangement of the density is presumed to be spatially homogeneous. The question of the existence of the disordered figure of equilibrium is governed by a non-linear integro-differential equation of infinitely high order. Special cases of this equation were first derived by Liapounoff The mode of derivation runs on lines parallel to those employed in the homogeneous case , but stronger singularities are exhibited, and a different method of treatment is required. The linear homogeneous approximation admits of trivial characteristic functions which can be eliminated by the method of division of the nucleus ; thus the relevant so-called trivial branch equations are identically satisfied, if one makes the assumption of symmetry corresponding to the hypotheses made in the earlier work.

The treatment of the non-trivial characteristic functions which may emerge, demands a detailed discussion from case to case. Once the non-linear equation has been freed, as above, the existence of the solution is proved by successive approximation. In the earlier work, potential-theory methods were adequate alone for demonstrating the convergence. This is not the case here , instead, a specific application of the theory of residues is needed. The latter device considerably simplifies the convergency proof for the special case of the homogeneous configuration.

From the very nature of the problem, the method cannot be elementary. Nevertheless, the Clairaut-Liapounoff problem (figure of the earth) shows that it can be explicitly carried through in all details. Keeping within the limits of strict mathematical theory, one arrives at the classical approximate results, Clairaut's differential equation and the like. The Clairaut-Liapounoff problem is solved partly independent of the general theory, so that one can manage with the scantiest possible assumptions about the radially symmetrical initial distribution.

Lichtenstein's paper is immediately followed, in the same journal, by a paper from Ernst Hölder on the same subject, " Zur Theorie inhomogener Gleichgewichtsfiguren. I. Mitt. Homogene Ausgangsfiguren." In earlier work, *e.g. Ber. Verh. sächs. Akad. Leipsig*, Math.-phys. Kl., 1926, Hölder has developed a method, on variational lines, affording mastery of the branch equations arising in geometrico-dynamical problems. This work is now extended so as to be applicable to Lichtenstein's researches in the case of weakly

heterogeneous figures. It permits the ignoration of the symmetry condition; further, it provides a dynamical interpretation for the parameters, and leads to a classification of the sheaf of equilibrium configurations.

A different treatment is adopted by N. Neronov. Writing, in Russian, "Sur une méthode de détermination des figures d'équilibre relatif d'une masse liquide homogène en rotation voisines des ellipsoïdes," *Bull. Acad. Sci. U.R.S S.*, VII, **2,** 215–27 (1933), he seeks a first approximation in a surface of the fourth order. The existence of such surfaces was known to Poincaré and Liapounoff. The method is to calculate the potential energy + centrifugal energy, and to choose the constant so that the equilibrium figure is a level energy surface. It is shown that a bifurcation ellipsoid is given in the Maclaurin series

ASTRONOMY. By R. W WRIGLEY, M.A., Royal Observatory, Edinburgh.

IRREGULAR VARIABLE STARS.—Many red stars of spectral classes M and N show irregular light variations, usually within fairly narrow limits A typical example of this class is α Orionis, and its great size and brightness make it a suitable subject for detailed study. Its variations in brightness were observed by J Stebbins between 1908 and 1931 with selenium and photoelectric cell photometers and the results appear in *Publications of the Washburn Observatory*, No. 15. Changes of brightness of short period less than a year he is inclined to regard as irregular, but a longer period variation of between five and six years seems definite and well established. A period of nearly the same length (5·781 years) was found by H. Spencer Jones in measures of the radial velocity of this star obtained at the Cape and Lick observatories, and this is accepted by Stebbins as fitting satisfactorily with his light fluctuation observations. Betelgeuse therefore resembles the Cepheid variables in this correlation between its velocity and light curves.

In the *Contributions of the Mount Wilson Observatory*, No. 464, Roscoe F. Sanford discusses spectrograms of the star obtained with high dispersion since 1923, and compares its radial velocity variations with measures of its angular diameter made with the interferometer at the same observatory, and also with Stebbins' mean light curve. The radial velocities agree well with Jones' as regards times of maximum and minimum, but the amplitude exceeds his by 50 per cent. The measured velocities vary from + 15·4 to + 27·0 km. per sec., but the changes are often considerable in a single season, and these cannot be represented by a simple period. But there

is a definite variation of Jones' period of 5·781 years which is marked by real maxima and minima, and the curve also shows agreement with Stebbins' mean light curve, though in both cases individual measures often stand out in a way which cannot always be ascribed to errors of observation.

An examination of the curves shows that maximum light occurs very nearly at the time when the radial velocity has attained its mean value and is decreasing, while the light is at its minimum when the velocity has the same value but is increasing. The relation between the mean light and velocity curves is therefore neither that of an eclipsing binary nor that of an ordinary Cepheid, and Sanford attempts to fit it to a theory of pulsation. If this is the true explanation the maximum and minimum diameters of the star should be reached as the radial velocity referred to its centre changes sign, and these times are apparently close to the dates for minimum and maximum light. It is therefore indicated that the star is at its brightest when its diameter is least, and vice versa. The change in radius is calculated as about 30 per cent on either side of the mean, making the surface area at its minimum only 0·3 of its value at maximum, but, as its light is greater by 0·4 magnitude, a five times increase in its actual surface brightness must be postulated. Direct measures of the diameter made by Pease with the interferometer show extreme values in harmony with this estimate, but they are as yet too few in number to enable the periodicity to be established with certainty. The measured diameter varies from 0·034 to 0·054 second, with the maximum coinciding approximately with the date for minimum light. Sanford also includes some comparisons with radiometric measures of the star made with the thermo-couple by Nicholson and Pettit, and though these are few in number they are in general agreement with Stebbins' results.

The surface temperatures at the times of maximum and minimum light, calculated from the apparent visual magnitudes and the radii of the star, are given as 3,430 and 2,950 degrees. Normally these temperatures would correspond to spectral types *g*K5 and *g*M3 respectively, but the spectrum of α Orionis remains at all times of class M and undergoes little if any change, the bands of titanium oxide being always present. One would naturally expect that so large a variation in surface brightness would be accompanied by a change in the effective wavelength.

In *Mount Wilson Observatory Contribution*, No. 465, Sanford deals with the spectrum and radial velocity of the star U Monocerotis, another of the irregular variables, whose magnitude varies

between 6·0 and 7·2 with an apparent period of about 46 days. It is, however, generally assigned to the RV Tauri group, and its period is taken as 92 days, containing two maxima and two minima of unequal and changeable heights and depths. This group of variables show certain similarities to the Cepheids, but vary more irregularly, sometimes having alternate deep and shallow minima, almost like eclipsing binaries. The spectra are of types G and K, and the group seems to form a small intermediate class between the Cepheids and the long-period variables. U Monocerotis is one of the brightest of their number, and was on this account selected for study.

A series of spectrograms obtained at Mount Wilson between 1922 and 1932, chiefly during the latter half of the decade, show that the light period of 92·26 days also fits the radial velocities, when a variation of 40 km. per sec. in the centre of mass velocity of period 2,300 days is eliminated. The radial velocities when thus corrected resemble the light variations in showing double maxima and minima in the one period. Changes also appear in the spectrum of the star. This becomes latest in class a few days before the times of minimum light, and these precede slightly the dates for maximum velocity. The latest spectral class therefore appears to occur when the radial velocity is increasing, while the earliest class accompanies a decrease, but they are not definitely related to the times of change from approach to recession and vice versa.

Though it is not yet possible to formulate any theory accounting for all the erratic changes of light, spectrum and velocity of these irregular variables, it is probable that they are all associated with fundamental properties of stellar matter and constitution, and that their further study will shortly lead to important discoveries.

The star RS Ophiuchi (Nova Ophiuchi, No. 3) is of great interest as forming a connecting link between irregular variables and novæ. This star was catalogued by Schönfeld as of magnitude 9·5 and was classed at Harvard as an ordinary variable. In 1898, however, it experienced a sudden outburst and reached mag. 7·69 at the end of June, relapsing to mag. 10·81 in October and remaining about mag. 11 with small irregular variations for over thirty years. Last August a new outburst was reported by E. Loreta of Bologna and L. C. Peltier of Ohio. On the 11th the magnitude was observed to be 5·8, the following day it attained its maximum of 4·3, by the 15th it had decreased to 6·4, and afterwards the decline continued steady and rapid. In a few days, therefore, it increased its light about 500 times, and its brightness at maximum was over

20 times greater than during the preceding outburst in 1898, though in the latter case it is possible that the real maximum was not observed, as there was a considerable gap in the observations before June 30. This revival of activity is very remarkable, and the only parallel case is afforded by the star T Pyxidis which has attained maxima greater than magnitude 8 on three occasions, in 1890, 1902, and 1920. It is possible that more of these recurrent novæ may be discovered, forming a class to bridge the gulf between true novæ and the U Geminorum variables

Previous to 1898 the spectrum of RS Ophiuchi was classed as K, but during the outburst of that year it was of nova type, with bright bands chiefly of hydrogen. A spectrum obtained at Mount Wilson in July 1923 when the magnitude was 11·5 was classified as G5, but it also showed strong bright lines of hydrogen and faint emission lines of ionised iron. Since the present outburst was reported the spectrum has been carefully studied, and accounts will be found in the *Publ. Obs Univ. Michigan*, V, No. 9, *Astronomische Nachrichten*, 5984, *Publ. Astronomical Society of the Pacific*, 267, and the *Observatory*, 1933, November. On August 16 the spectrum was characterised by strong, broad, bright bands of hydrogen, fainter emission bands of helium, ionised iron and calcium, and a strong continuous spectrum. The bands showed a peculiar structure, for they had no definite outer edges and were sharply divided at their centres, the violet half being much the weaker It seemed that a general diffuse absorption was taking the place of the relatively sharp absorption lines which appear at the violet edges of bands in typical nova spectra. The latter indicate the presence of one or more shells of gas ejected from the star with different velocities, but in the case of RS Ophiuchi it would seem that the gases were driven off continuously with a large range of velocity, and not as separate shells. Interesting changes were observed at Mount Wilson between August and October. On August 18 the nebular line λ 4363 was first observed as a faint, sharp emission line, while by the end of the month five nebular lines could be easily measured, and strong bright bands of ionised nitrogen and helium had appeared. On October 2 the green coronal line was prominent, and another strong line at λ 6374 was identified with considerable certainty as the red coronal line. This is remarkable as the first occasion on which the coronal lines have been found in the spectrum of any star. Deriving their name from their presence in the sun's corona they were once supposed to be due to an unknown element, but they are probably unfamiliar lines of known elements which appear only under special conditions of tenuity and

excitation. In *Publ. Ast. Soc. of the Pacific*, 268, it is stated that still later spectrograms obtained at Mount Wilson show no fewer than five coronal lines at $\lambda\lambda$ 3987, 4086, 4231, 5303 and 6374. But the faintness of the star and the structure of the lines prohibit any high degree of accuracy in the measures.

Eclipsing Variables.—The star β Lyræ may be taken as a type of a group of eclipsing variables, which are interesting for the light they throw on the problem of the origin of binary systems. If these are produced by the fission of a single star, the division must take place under the influence of increasing rotation, and the separation of the two components must gradually increase through tidal friction. Thus pairs of short period are transformed in time into those of longer period, and on this assumption β Lyræ must represent an early period in the life of a double star. It is a system consisting of a super-giant primary revolving in 12·92 days round a darker and much more massive emission star, both components being of great diameter and extreme tenuity, and their surfaces are almost in contact. They eclipse each other for four days, and the times of maximum light correspond to the elongation of the stars in their relative orbits.

In the *Annals of Harvard College Observatory*, **84**, No 8, Miss Antonia C. Maury gives the results of a ten years' study of a series of Harvard spectrograms of this star, taken during 1886–1901 and during 1921–31. She finds that the nearness of the stars to one another affects the phenomena on their inner and outer edges, probably by producing variation in gravity and tidal influences. The cyclical changes which appear in the spectrograms are attributed to the alterations in the positions of the two stars with respect to each other and to the observer, for apparently they are by no means alike on all sides. The more massive star shows an emission spectrum, type B2*e*, which is remarkable for the great strength of its bright helium bands. Strong emission is produced on its outer limb, and the lines are thrown alternately towards the red and the blue by the Doppler effect of rotation, being probably produced in the tidal protuberances which are the region of the most intense spectral phenomena. The primary, but less massive, star is of spectrum *c*B9, and is in very rapid rotation. The main phenomena observed can be explained on the assumption that both stars consist of bright central discs surrounded by very deep, rarefied and largely transparent envelopes. The emission lines have their origin in the envelope surrounding the secondary, in harmony with the fluorescence theory of the origin of bright lines. Certain complications are, however, caused by the existence of an irregular

variation in addition to the cyclical changes, and so far all attempts to fit this to a definite period have failed.

In the *Astrophysical Journal*, 78, No. 3, William Markowitz considers the assumption that widely separated eclipsing binaries have been formed from close pairs by a process of contraction. If this be true, the densities of those binaries whose separation is large should be systematically higher than of those whose surfaces are nearer together, assuming an equal initial density for all the systems when their components were in contact. Markowitz makes a statistical examination of 125 systems, arranging them first with respect to density as close, medium and wide pairs, and secondly with respect to their spectral types, which might be expected to be altered by contraction. It is found that the distribution of the observed eclipsing binaries with respect both to density and to spectral type is quite independent of the separation. This can only be explained by assuming either that the stars have not contracted, or that the densities at which division into two components took place were systematically much smaller for those pairs which are now widely separated. The author expresses the view that the former alternative is the correct one, and that eclipsing binaries with large separation have not been formed from those of small separation by a process of contraction.

A continuous loss of mass by radiation has been proposed as an agent by which the short period of a spectroscopic binary might be gradually lengthened, but Markowitz fails to find any indication of a decrease of mass accompanying an increase in period, and concludes that these binaries have not lengthened their periods by this method. When arranged in groups according to their periods the average mass remains the same, being about three times that of the sun. A similar result has been reached by E. Öpik from a study of visual binaries (*Popular Astronomy*, 1933, February). This failure to detect any progressive change in the stellar masses admits of two explanations. A short time scale for the life of the galaxy in its present form, such as is required by the concept of an expanding universe, would not afford the opportunity for any significant changes to take place either in the orbits or the masses of binary stars; in a period of 10^{10} years the sun would lose only 0·1 per cent. of its mass, assuming its present rate of radiation as constant. Or the loss of mass by radiation may possibly be balanced, on the average, by a star picking up interstellar matter on its journey through space, as was originally suggested by W. D. MacMillan. At present it seems that the density of interstellar matter is too low to provide full compensation, but more information

is required concerning the extent, masses and densities of the gaseous nebulæ before a reliable judgment can be pronounced.

In the second part of his paper Markowitz discusses some dynamical phases of the process of the fission of stars, with application to the β Lyræ variable W Crucis, and to Capella. He concludes that if these binaries were formed by fission the density of the cores of their parent stars must have been of the order of 10^{-4}gm/cm^3, and that they were therefore gaseous and not liquid. According to his analysis a gaseous star is not subject to fission if the ratio of its mean density to that of its central core is less than 0·37, for then it will break up by shedding matter at its equator. He is, indeed, sceptical as to whether fission of a star ever really occurs, and his views on the subject of the origin of binaries are therefore very different from those of Jeans, as expressed in his *Astronomy and Cosmogony*.

PHYSICS. By L. F. Bates, Ph.D., D.Sc., F.Inst.P., University College, London.

At the January meeting of the Royal Society this year A. O. Rankine described a very simple but exceedingly sensitive method of demonstrating the paramagnetic and diamagnetic properties of substances in magnetic fields of low intensity. It represented the outcome of attempts (*Phys. Soc. Proc.*, **44**, 465, 1932, **46**, 1, 1934) to construct a magnetic gradiometer for the measurement of small local distortions of the earth's magnetic field, in the same way that the Eötvös torsion balance measures distortions of the gravitational field.

Rankine's instrument virtually consists of a light horizontal cross-bar suspended by a vertical fibre of very low torsion constant. To one end of the cross-bar is connected a vertical cobalt steel magnet by means of a silk fibre; to the other end is similarly connected a brass rod of mass equal to that of the magnet. The latter is about 5 cm. long and weighs about 8 gm. The whole system takes up an equilibrium position which is practically independent of H, although no special mounting devices appear to be necessary to give this very desirable independence. On bringing a cylinder of a weakly magnetic material close to the magnet, both poles will attract it if the substance is paramagnetic, or both repel it if diamagnetic, and the system will be correspondingly deflected. Actually, the material is so placed that only the upper pole of the magnet is effective, and a hollow copper cylinder placed around the lower pole provides sufficient electromagnetic damping to render the system almost dead beat.

The main difficulty encountered in the construction of the

instrument is that of obtaining metals free from ferromagnetic impurity. The instrument described above is at present encased in brass. Now, it is exceedingly difficult to get really iron-free brass, and an iron content of one part in a hundred thousand has a very considerable effect on the system. This difficulty is now being tackled and will undoubtedly be overcome. The deflection produced by water, which is weakly diamagnetic, is quite considerable, and it seems likely that the instrument can be adapted for experiments with gases, for there is a possibility of reducing the control exerted by ferromagnetic impurities and by the fibre to such an extent that fifty times the present sensitivity will eventually be obtained.

An eddy current effect which is at first observed on introducing a metal into the apparatus is very interesting; it results in a temporary deflection simulating temporary diamagnetism of the metal under observation. The values of susceptibilities so far measured are of the same order of magnitude as those measured by methods which require fields over one hundred times as large as those used in the new instrument. Exact numerical agreement has not yet been proved, but, as Rankine pointed out, we cannot state with any assurance that they should be exactly equal, and that is one reason why the further removal of ferromagnetic impurity will be awaited with interest. The method of high fields is generally assumed to permit the elimination of the effect of such impurities by using Owen's formula (*Science Progress*), but the writer of this article feels that its application is sometimes dangerous, *e.g.*, in the case of manganese.

The frequent references in the American literature to the Allison method of recording the presence of isotopes make it desirable to give an account of the method here. When a beam of plane polarised light passes through a substance in a magnetic field in a direction parallel to the lines of force, the plane of polarisation is rotated. This effect is known as the Faraday effect, and, as far as one can see, the Allison method is based on the lag of the Faraday effect behind the magnetic field which produces it.

The experimental arrangements (*Phys. Rev.*, **30**, 66, 1927) may conveniently be pictured as follows. Let us suppose that we have four long parallel wires which we may call A, B, C and D respectively, running from left to right, B and C being much farther apart than A and B or C and D. Let us connect A and B together on the right and on the left sides by movable trolleys, and do the same with C and D. Now cut B and C at their mid-points and join the left segment of B through a solenoid to the left segment

of C. Similarly, join the right segment of B through an identical solenoid to the right segment of C. Finally, connect the mid-point of A to one plate of a suitable condenser and the mid-point of D through a spark gap to the other plate. Let the condenser be periodically charged and discharged by an induction coil, so that electrical surges are sent through the solenoids, which are placed with their axes in line but with their fields in opposition Then it can be arranged that the two magnetic fields are equal in magnitude at every instant of their growth and decay, simply by adjusting the trolleys, say, those on the right.

Now, the spark which produces the surges may also be used as a source of light This light can be passed through a polarising nicol, then through the solenoids, and through an analyser to the eye of an observer. In each of the solenoids is placed a glass cell initially containing carbon disulphide, and there is no resultant Faraday effect if the adjustment of the magnetic fields is complete Since the light passes first through one cell and then through the other, the crossed nicols will stop all light only when the trolleys are displaced or the solenoids are moved to allow for the time taken for the light to pass from the centre of one solenoid to the centre of the other.

If the liquid in one of the cells, usually the right, is changed, darkness will only be obtained when the trolleys (or the solenoid concerned), are moved to new positions. Actually, complete darkness is no longer obtained, because the Verdet constants of the two liquids are not equal, and only a minimum transmission can be observed. Hence the method of examination of a liquid consists in recording the displacements of the trolleys (or of the cell), which are termed scale readings. Apparently, all workers do not find it easy to make consistent observations, and special powers of observation seem necessary. A photoelectric cell circuit has been used to replace the eye, but does not at present appear to be really effective.

We will now review some of the results so far obtained. The scale readings of solutions of the chlorides, nitrates, sulphates and hydroxides of many metals have been found. On plotting the logarithm of the chemical equivalent of the metal against the scale reading corresponding to minimum transmissions, each group of substances gave points lying on a smooth curve, with just a few exceptions, such as cadmium. The main trouble in attempting to use the method for qualitative analysis was the effect of impurities, for the minima appear with almost the same distinctness over a huge range in concentration. However, it has been successfully

used to detect the presence of rare elements, and in this way Allison and Murphy (*Phys. Rev.*, **35**, 285, 1930) found evidence of the element 87, and Allison, Murphy, Bishop and Sommer (*Phys. Rev.*, **37**, 1178, 1931) found evidence of element 85.

The importance of the method in the examination of isotopes is that the number of minima obtained with a liquid is usually equal to the number of isotopes, because each isotope appears to act as an independent substance. The differential time lags of the isotopes of a given element appear to vary directly with the atomic masses of the individual isotopes. Exceptions to these rules are apparently provided by lead and barium where four minima were observed in each case, while the numbers of isotopes reported are eight and three respectively. It is of considerable interest that hydrogen in acids and water gives two minima quite close together (*J. Amer. C. Soc.*, **52**, 3796, 1930). Presumably, these minima are due to H^1 and H^2. Accurate estimates of their abundance could not be made, but it was suggested that the heavier isotope is present in the ratio of one to several thousands of the lighter. More recently, Latimer and Young (*Phys. Rev.*, **44**, 690, 1933) have examined the minima with a solution of hydrochloric acid in water containing 2 to 4 per cent. of heavy hydrogen. They found a third minimum which corresponded to H^3, its intensity being somewhat less pronounced than the minimum of H^2 in ordinary water. These results have been checked with solutions of hydrobromic acid. The method is clearly an interesting and important one, but many points in the technique and conclusions still remain obscure. A few have recently been cleared up to some extent by Snoddy (*Phys. Rev.*, **44**, 691, 1933), who has also confirmed the results with the isotopes of lead.

It is convenient here to draw attention to a very careful determination of the susceptibility of water by Auer (*Ann. der Phys.*, **18**, 593, 1933) who gives the value $0{\cdot}72145 \pm 0{\cdot}00048 \times 10^{-6}$ c.g.s. units per gm. at 16·3° C. He used a modified Quincke method in which the rise of the water in a tube in a magnetic field was compensated by a rotation of the whole system of which the tube formed a rigid portion, about a horizontal axis. In this way disturbances caused by changes in volume were avoided. Auer (loc. cit., 613) has also described a method for the absolute measurement of a magnetic field of the order of 8,000 gauss, a measurement which is not as easy as is generally supposed.

Reference has previously been made in this section to developments in the technique of focusing beams of electrons by what are termed electrostatic and magnetic lenses devised by German

workers. A simple magnetic lens is a coil of wire, often quite flat, surrounding the discharge tube. A converging electrostatic lens may be formed by a metal tube maintained at a negative potential down which the electrons pass, later to emerge through a hole in a positively charged disc placed a short distance outside the end of the tube. This work is important because theory indicates that extremely high resolving power may be obtained if the aberrations and imperfections of such lenses can be overcome. Indeed, some optical workers speak optimistically of the focusing of the electrons in a diffraction ring system in order to obtain further information concerning the structure of thin films.

One of the latest communications by Brüche (*Zeit. für Phys.*, **86**, 448, 1933) describes an experiment in which a zinc plate is strongly illuminated by ultra-violet light and the photo-electrons thus liberated are accelerated by a potential difference of 30 K.V. The electrons pass through a brass tube anode and are focused by a magnetic lens, an enlarged picture of the zinc plate can thus be obtained on a photographic plate. Such pictures are remarkably clear. In England, L. C. Martin and his collaborators are working with 800 volt electrons which are passed through a wire gauze or other transmission object and then focused with an electrostatic or magnetic lens. The process was demonstrated with striking success at the Physical Society Exhibition in January last when images, magnified fifteen times, were projected on to fluorescent screens. The general conditions for the calculation of achromatic electron microscopes have recently been set out by Ardenne (*Zeit. für Phys.*, **86**, 802, 1933) who shows that it is possible to arrange a converging system consisting of a magnetic converging lens and an electrostatic diverging lens. He also describes the construction of a suitable magnetic diverging lens and gives diagrams of the construction of the above combinations.

In a paper on atomic constants deduced from secondary cathode ray measurements, Robinson, Andrews and Irons (*Proc. Roy. Soc.*, **143**, 48, 1933) describe magnetic spectrum measurements on the photo-electrons emitted from gold, tungsten, copper and silver when exposed to CuK X-radiation. From a knowledge of the velocities of two groups of photo-electrons the difference in energy of the levels from which they arise may be calculated, and the difference so obtained may be compared with that derived from X-ray data of the same levels. To make the first calculation a knowledge of e/m_0 and e/h is required, these were respectively taken to be $1{\cdot}759 \times 10^7$ e.m.u. per gm. and $7{\cdot}290 \times 10^{16}$ e.s.u. per erg per sec.

On these assumptions a difference of about 0·5 per cent. is found between the results from photo-electron data and the results from X-ray data. The authors draw attention to the interesting fact that a value of h/e may be determined from a knowledge of the Compton shift, h/m_0c, determined by Gingrich (*Phys. Rev.*, **26**, 691, 1925), and e/m_0. The value of h/e thus obtained is $1{\cdot}3796 \times 10^{-17}$ erg sec. per e.s u., a value which brings the above photo-electron and X-ray data into agreement They also point out that Meibom and Rupp (SCIENCE PROGRESS, XXVII, 203, 1932) found h/e from the diffraction of fast electrons to be $1{\cdot}3798 \times 10^{-17}$, the limits of experimental error being $\pm$ 0·3 per cent. It is extraordinary that two such diverse methods, the one involving the scattering of photons and the other the scattering of electrons, should yield values in close agreement with each other and yet differing by as much as 0·5 per cent from the value usually accepted as being correct.

METEOROLOGY. By E. V NEWNHAM, B.Sc., Meteorological Office, London.

METEOROLOGY and aviation have shown themselves to be very interdependent ever since the early days of ballooning, when meteorological instruments were taken up to great heights in manned balloons and furnished the earliest information about the temperature and humidity conditions of the free atmosphere, and when in return the balloonist must have been glad of any information about upper winds that meteorologists were able to furnish from the records of mountain observatories and observations of cloud motion It is interesting to note also that much early information about the meteorology of the first few thousand feet of the free atmosphere was obtained by instruments attached to kites, and that it was the kite that suggested to many early aviators that the problem of heavier-than-air flight might eventually be solved without the necessity of imitating mechanically the combination of strength, flexibility and lightness shown in a bird's wing. In more recent times upper winds have been studied with the aid of pilot balloons to such an extent that the number of observations is almost embarrassing to a student of the general circulation of the atmosphere, while specially equipped aeroplanes are to be found in most countries, whose purpose is to supply daily information about the temperature and humidity up to a height of 20,000 feet or more. It probably would not have occurred to the average meteorologist to see a new means of advancing meteorological knowledge in the method of experiment with the aid of what is known as a "wind tunnel" that has been developed at the National Physical

Laboratory, Teddington, and elsewhere in recent years. This method owes its origin mainly to the difficulty of treating mathematically the air motion and the forces set up by obstructions opposing the movement of a wind current, and the consequent difficulty of predicting the behaviour of new types of aircraft.

In the early days of aviation knowledge was often acquired at great expense, and often with loss of life, by trial flights with untested designs The new method makes use of the fact that comparable information can be obtained by observation of a small model suspended in an artificially produced wind current In meteorology there are many wind phenomena that are analogous to those associated with disturbances of smooth flow set up by the obstruction caused by the different parts of an aeroplane ; it has long been known that the gustiness of the wind is greater in the lee of tall objects such as houses and trees than in open country, and is due to the eddies set up by such obstructions When, therefore, accidents occurred to aeroplanes in the Bay of Gibraltar owing to exceptional air-currents set up by the Rock of Gibraltar in easterly winds, and the Air Ministry undertook an investigation of the matter, those charged with this task began by having a model made of the Rock, which was tested in a wind tunnel at the National Physical Laboratory, with a reasonable expectation of finding out the distribution and type of the eddies set up by the Rock. It was not expected that the method could be used to determine in advance the rates of formation and variation of the eddies or the actual strengths of the up-and-down currents, consequently the preliminary enquiry at Teddington was followed by work at Gibraltar with pilot balloons and kites carrying special instruments to verify the type of motion and obtain the further information required. The results are given in detail in a recent publication of the Meteorological Office.[1] The usual methods for studying the degree of turbulence of the wind in the wind tunnel and for recording its "pitch" from the horizontal and "yaw" from the steady wind direction, were seen to be too lengthy and to be needlessly accurate for this enquiry ; they were accordingly replaced by two new methods. One of these was to set up numerous fine silk fibres as flags to indicate wind direction, these being supported on extremely fine transverse wires ; the other was to use five woollen streamers varying from 7 to nearly 30 inches in length, attached to thin steel pins fixed upright in the base-board. The

[1] *Geophysical Memoir*, No. 59. "A Survey of the Air Currents in the Bay of Gibraltar, 1929–30," by J. H. Field, C.S.I., M.A., and R. Warden, Ph.D., M.Eng., 1933. H.M. Stationery Office, 5s. net.

first method showed the motion in great detail while the second was more effective in bringing into prominence the larger vortices, in spite of the fact that the pull on those parts of the streamers farthest from the supports somewhat distorted the shapes of the parts nearer to the supports. Variations of wind direction were provided by altering the orientation of the model in the wind tunnel, but in the memoir referred to only directions corresponding with winds from 60°, 75° and 90° east of north are discussed.

These methods at once suggested that in strong easterly winds there is an area of vortices and eddies which extends for about a mile and a half westwards from the Rock up to at least a height of 3,000 feet (more than twice the height of the Rock), followed farther west by a wide region of turbulence of gradually diminishing amount. There was observed also, as might have been expected, a rotation of the axis of disturbance when a shift of wind from due east took place, but an unexpected result was that there was also a translation of the whole area such that with a north-east wind the axis of disturbance began near the south end of the Rock, while with a south-east wind it began near the north end. This means that the winds were diverted temporarily before passing over the Rock.

With due east winds two nearly equally large permanent vortices with curved axes ending vertically on the seashore were formed, which extended far to the west of the ridge. These eddies showed rather complex changes with a change of wind from due east. The one nearest to the end of the ridge which is turning as it were into the wind—the north end when the wind backs towards north—increased in size, while the other diminished. At the same time the axes of both turned gradually from the vertical towards the horizontal. When the wind direction had changed to 30° north or south of east only a single vortex remained, with an axis extending down wind horizontally for at least four miles. The regions between these vortices were regions of great turmoil, the wind sometimes descending from at least 3,000 feet to the sea level while travelling only three-quarters of a mile horizontally.

It was not found practicable, of course, to verify in every detail the results obtained in the wind tunnel by observations on the spot, but conditions were tested at a sufficient number of points to show that the general character of the air motion over the Bay itself had been accurately portrayed. Between November 1929 and March 1930, observations of the horizontal and vertical components of the wind over the Bay were obtained in 138 pilot balloon ascents to test the rapidity of the changes as well as to obtain in-

formation about actual velocities. It was found that down-currents were on the whole stronger as well as more frequent than up-currents, and it was concluded that vertical speeds of 20 miles an hour or more are reached over short periods of time such as a quarter of a minute, even on days when the wind force on the Beaufort scale is only 6 (a strong breeze)

This investigation was successful in regard to the immediate practical problem—that of mapping the areas that are dangerous for aviators for particular directions of wind in the undisturbed surroundings of Gibraltar, but had a wider success in that it opens out a new line of investigation for the study of local winds and squalls. An important part of the work of those meteorologists who cater especially for the needs of aviation is the judging of the suitability of a proposed site for an aerodrome from the point of view of possible dangers to landing machines arising from local eddies or vortices, or from vertical currents, and the method of indirect experiment in the wind tunnel is probably of wide application in such problems.

Another method of investigating atmospheric eddies is based on the interpretation of the rapid changes in the force and direction of the wind revealed by the continuous record of these quantities obtainable with the aid of a Dines Pressure Tube anemograph. The height to which such investigations can be extended is, of course, limited by the need for providing a tower to carry the hollow vane, and the pipes connected to it, which in this instrument enable the variations in atmospheric pressure at the forward end of the vane to operate on a float carrying a pen which records wind speed at the same time that the variations of the direction towards which the vane points are recorded by pens operated by the bottom end of the mast which supports the vane. The gusty or squally character of the wind shown on the record of such an instrument, which is known technically as an anemogram, has long been known to be an indication of atmospheric eddies, a temporary increase of wind speed being due to the horizontal component of the eddy movement at the wind vane having such a direction that it reinforces the general average wind current prevailing at the time, while a lull represents a situation where the eddy movement opposes the general current. It was recognised further that there are regions where the horizontal component of the eddy movement does not coincide with the general direction of the wind, and where it causes a temporary change of wind direction which is shown on the anemogram by a departure from the line of average wind direction. But the interpretation of the anemogram has been

greatly advanced by the work of the late M. A. Giblett and other members of the staff of the Meteorological Office at the Royal Airship works at Cardington, an account of which is given in *Geophysical Memoir*, No. 54, of the Meteorological Office. In that work six Dines anemographs at different heights some distance apart were employed so that much more information could be obtained about individual eddies than is obtainable from anemograms for a single point in space.

Another device was employed in order to obtain more detailed information about the air movement, and that was to speed up the rate of revolution of the recording drum on which the anemogram is fixed. In the ordinary instrument the drum, which is driven by clockwork, revolves once in twenty-four hours, and in a very gusty wind the individual excursions of the pen often cannot all be followed owing to the very short horizontal distance between them. By using clockwork that caused the drum to rotate once in ten minutes a magnification of 144 was introduced in the horizontal time scale, and this enabled all excursions of the velocity and direction pens to be recorded. Of course, the inertia of the moving parts of the anemometer, and particularly of the float used to record velocity, damps out many small or very brief changes and oscillations are liable to be set up, which are of instrumental origin, but these difficulties did not prevent great advances in our knowledge of atmospheric eddies and wind structure from being made. The so-called ultra-quick-run records obtained in the way just described enabled Mr. C. S Durst, one of those engaged in this research, to make an important new classification of atmospheric eddies into two broad types, and to offer a very plausible explanation of their mode of origin. These types are:

(1) Small very irregular disturbances, of short period, having their axes in all directions and thus imposing on the main wind stream fluctuations from the average speed that have the same average magnitude in all directions.

(2) Larger disturbances of a totally different kind with a much smaller percentage variation of size in given conditions and not having axes in all directions.

In the introduction to the memoir already referred to the effects of these two types of disturbance are shown on a specimen illustration of part of an ultra-quick-run anemogram. The second type is indicated by a rapid increase of wind speed from 20 to 33 miles an hour in a few seconds and then a gradual fall for about three minutes, accompanied by smaller increasing fluctuations of both speed and direction of very short period, to an average speed of

rather less than 20 miles an hour. These smaller fluctuations are eddies of the first type, and are found to occur under all conditions except those of extreme vertical stability represented by a very pronounced increase of temperature from the ground upwards. In Durst's theory they are caused by eddies set up by friction in the main air stream, the friction being the result of obstructions such as houses and trees. Under conditions of extreme stability such eddies are quickly damped out, which explains their disappearance when a big "inversion" of temperature appears. The larger disturbances are found to occur most often with an adiabatic or super-adiabatic lapse-rate of temperature, *i.e* when there is vertical instability in the atmosphere favouring up and down movement; they disappear almost entirely when an inversion of temperature appears, as, for example, is commonly the case when the temperature near the ground falls quickly after sunset under a clear sky. The characteristic of suddenness of rise of wind speed combined with a slow decrease superimposed on rapid smaller fluctuations which on an average become more marked as the slow general decrease of speed takes place, was found to be normal with the second type of disturbance, and a theory was formed by Durst which fitted the observations very well. In his view these are convectional disturbances in the form of "cells" travelling with the general wind, the convectional circulation being upwards at the rear of a cell, forwards at the top, downwards in front and then backwards near the ground, these movements being referred in every case to the general average wind between the ground and the top of the cell.

The first part of a cell to be encountered by an observer on the ground will be the front, which contains air that has the relatively high velocity of the winds of the upper levels and their relatively small irregular turbulence, the result being a rise of wind speed and a decrease of small-scale fluctuations. As the "gust front" passes away wind is encountered which has been near the ground for an increasingly long time, and the average speed decreases while the frictional eddying becomes greater until the whole cycle is repeated by the arrival of the gust-front of another convectional cell.

There are of course other changes, *e.g.* in temperature and humidity, to be expected when air that has been travelling along the ground is suddenly replaced by newly descended air, and consideration of these was found to give support to the theory. On a day when convectional clouds are present in the sky, the tops of these clouds would represent the tops of the rear portions of such cells where the ascending currents have caused cloudy con-

densation as a result of dynamical cooling, and the clear spaces between the clouds would be found over the front parts, where the descending currents lead to dynamical warming and evaporation of the cloud. Analysis of the wind records at Cardington showed that the convectional cells generally had a length of between 3,000 and 8,000 feet down-wind, and that they generally extended at least up to a height of 1,500 feet; it was concluded that they were considerably less extensive at right angles to the wind than down-wind. The frictional eddies were on an average much smaller, having diameters up to 50 or 100 feet.

Further evidence in support of the theory of convectional cells has been obtained by studying the structure of convectional cells produced artificially in fluid arranged so as to show the general increase of velocity and change of direction of flow with height that is normally observed in the atmosphere. The fluid used was amyl acetate and convection was set up by evaporation from the surface of the fluid, which caused cooling there, and resulted in instability. The convectional circulation was made visible by suspended particles of aluminium. The cells were found to be of horse-shoe shape in horizontal section, the descending fluid being on the periphery. The atmospheric cells are believed to be of similar shape.

BIOCHEMISTRY. By W. O. Kermack, M.A., D.Sc., Royal College of Physicians' Research Laboratory, Edinburgh.

Biochemistry of Muscle.—The general picture of the biochemical mechanism associated with the process of muscular contraction was radically altered after the discovery, in 1925, by Eggleton and Eggleton of the labile phosphorus-containing compound which they named phosphagen and which was later isolated and identified as creatine phosphoric acid. A large number of experimental facts of various types, when taken together, suggest the following picture of the biochemical mechanism associated with the contraction of skeletal muscle.

Upon stimulation of the muscle, phosphagen breaks down into its constituents, creatine and phosphoric acid, and the energy liberated in this reaction supplies the energy needed to enable the muscle to perform the mechanical work. After the contraction process has finished, the phosphagen is resynthesised at a rate relatively slow in comparison with the more or less explosive breakdown process. The energy necessary for the resynthesis of phosphagen would appear, in the skeletal muscle, to come for the most part from the anaerobic breakdown of glycogen or glucose into

lactic acid. The lactic acid is subsequently oxidised to carbon dioxide and possibly partly reconverted back into glycogen as sufficient oxygen gradually becomes available. The fact that the resynthesis of the phosphagen can be brought about by the anaerobic glycolysis makes it possible for the muscle to develop, during short periods, amounts of energy much in excess of that which would be possible were it dependent upon the immediately available supplies of oxygen.

In a recent series of papers, Clark, Gaddie and Stewart and Clark, Eggleton and Eggleton have investigated in detail the metabolism and biochemistry of the frog's heart (*J. Physiol.*, 1931, **72,** 444; 1932, **75,** 311, 322; 1933, **77,** 432: *J. Physiol*, 1931, **72,** 25 P.; **73** P., 1932, **75,** 332). There are many interesting points of comparison between the heart muscle and skeletal muscle, both contain phosphagen, but the concentration of phosphagen is less in the resting heart muscle, the average values being about 6·5 mg. P. per cent. in heart muscle and 65 mg. P. per cent. in skeletal muscle. In both cases the contraction process is accompanied by disappearance of phosphagen and the appearance of orthophosphoric acid, but the general metabolism in other respects seems at first sight to present a striking contrast. The heart muscle, when supplied with oxygen, can go on beating for many hours during which time very little lactic acid is produced Oxygen is consumed at about 2 c.c. per hour, but determinations of the carbohydrate show that at most 40 per cent. of this oxygen can have been used to oxidise carbohydrate. Fat was not the source of the energy as it remained practically constant. From the fact that urea and ammonia diffuse from the heart into the supernatant fluid it is concluded that a significant part of the energy, possibly up to 40 per cent., is derived from the oxidation of protein. In many experiments only about three-fourths of the oxygen uptake was accounted for and the fate of the other quarter is still unknown. In any case it is evident that the frog's heart muscle, beating normally in Ringer's fluid, derives its energy preponderantly from an aerobic reaction and that glycolysis, with formation of lactic acid, appears to play no significant rôle. Glucose added to the Ringer's solution, even in presence of insulin, is not utilised by the active heart.

With restriction of the oxygen supply a very different series of results has been obtained. In ordinary neutral Ringer, lactic acid rapidly accumulates in the heart muscle and the mechanical action soon ceases. In alkaline Ringer (containing sodium phosphate or bicarbonate) the lactic acid does not accumulate much but passes out of the muscle, and if the p_H of the Ringer is not allowed

to fall below about 8·0, the heart may go on beating for many hours provided sufficient supplies of carbohydrate are available. During all this time, lactic acid is steadily produced either from the carbohydrate originally present in the muscle or from added glucose. The contrast with the aerobic heart, which does not utilise glucose, is noteworthy. In the heart muscle the energy of anaerobic glycolysis would seem to be called upon only when the normal processes are prevented by restriction of oxygen supply.

The behaviour of the phosphagen in the anaerobic heart is very interesting; it falls to quite a low level but never entirely disappears; the concentration is usually about 1 mg. per cent., and it has been calculated by Clark, Eggleton and Eggleton that this concentration is enough to provide the energy for at least one beat. Thus the very small concentration of phosphagen found in those anaerobic hearts is consistent with the view that this substance plays an essential part in the mechanical process and is the source of the energy of contraction.

It is now some years since Lundsgaard discovered that iodoacetic acid (CH_2ICOOH) in small concentration has a remarkable specific action in that it inhibits the anaerobic breakdown of glucose into lactic acid by muscle, or into alcohol and CO_2 by yeast. Bromoacetic acid has a similar action, although rather higher concentrations are required, but chloroacetic acid is inactive. It has now been shown that small concentrations of iodoacetic acid (1 : 50,000) have little effect on the heart beating aerobically, but that the anaerobic heart, beating in alkaline Ringer, is highly sensitive to the acid in this small concentration. When the poison is added, the heart comes to a standstill after a few minutes. The conversion of glucose into lactic acid has now been inhibited and the minute amount of phosphagen in the anaerobic heart is insufficient for more than a few beats. If, on the other hand, the oxygen supply is stopped to a heart already treated with iodoacetic acid, it comes to a standstill in 50–100 beats and it would seem that during this time it derives its energy partly from the residual oxygen in the tissues and subsequently by using up the supply of phosphagen, which in the case of the aerobic heart is more ample, being of the order of 6·5 mg. per cent., until only about 1 mg. per cent. is left. At this stage, provided the poisoning is not allowed to proceed too far, the heart can be revived by the admission of oxygen, but with prolonged poisoning the phosphagen completely disappears and the heart goes into permanent rigor and cannot be revived. As is to be expected, during iodoacetic acid poisoning the hearts are unable to utilise glucose added to the Ringer nor do they produce lactic acid.

We have thus in the case of the beating frog's heart a picture involving three distinct mechanisms. (1) The phosphagen mechanism in which phosphagen, by breaking down into creatine and phosphoric acid, supplies the energy for contraction and by the energy derived from (2) or (3) is almost at once resynthesised ; (2) Aerobic oxidation apparently chiefly of protein and in a minor degree of carbohydrate, not yet clearly understood but definitely insensitive to the action of iodoacetic acid , and (3) the conversion of glucose into lactic acid, a process not requiring a supply of oxygen but highly sensitive to iodoacetic acid. These results raise the important question—to what extent the processes in skeletal muscle and in heart muscle are the same. It may be that the differences are superficial and incidental and that the contraction of isolated skeletal muscle is usually associated with lactic acid simply because it is difficult to provide an efficient oxygen supply. It is possible that skeletal muscle also possesses an aerobic mechanism analogous to that in heart muscle but perhaps differing in relative importance corresponding to its different functions and conditions of activity.

A very interesting and promising line of investigation has developed out of the above work. It has been mentioned that the anaerobic heart beating in alkaline Ringer can utilise glucose added to the perfusion fluid. In fact, it is found that after it has exhausted its own available carbohydrate supply (which amounts to about 80 per cent. of its total carbohydrate ; about 20 per cent. being apparently not utilisable for lactic acid formation), it becomes entirely dependent on the glucose which it takes up from the perfusion fluid and in the absence of available fuel soon comes to a standstill.

It is obvious that this provides a method for testing the availability of various compounds as suppliers of energy for the anaerobic mechanism of the heart muscle and it would seem likely that light would be shed on the chemical reactions involved in the glycolysis by the examination of suitably chosen compounds. For instance it might be expected that intermediate products of metabolism would be able in whole or in part to replace glucose. Investigations of this type (*J. Physiol.*, 1934, **80**, 457) carried out by Gaddie and Stewart show that of a large number of carbohydrates and related substances tested only mannose could replace glucose. Fructose, it is interesting to note, was not active. Of various compounds (including pyruvic acid) which have been suggested as intermediates of carbohydrate breakdown, which were examined, only methyl glyoxal produced recovery, though not quite so efficiently

as did glucose. This result may be of very considerable importance in view of the fact that a scheme which has recently been suggested as a description of the course of lactic acid formation does not involve methyl glyoxal. Muscle biochemistry sustained a grave and regrettable loss in the course of this last year by the death of Gustav Embden, who proposed the scheme referred to above. In a lecture (*Nature*, 1933, **132**, 337) Meyerhoff has expressed his general agreement with Embden's views and suggested an analogous series of reactions in connection with the process of alcoholic fermentation. The scheme is shown briefly by the following set of reactions, and it will be seen that the three phosphoric esters, glycerophosphoric acid (V), glyceraldehyde phosphoric acid (II) and phosphoglyceric acid (IV) play essential parts in the set of reactions, whilst pyruvic acid (VI) and not methyl glyoxal is the precursor of lactic acid (VII). Both methyl glyoxal and pyruvic acid have been identified by Case and Cook (*Biochem. J*, 1931, **25**, 1319) as being present in frog and rabbit muscle.

A. Glycogen or glucose ⟶ hexose diphosphate (probably through aldose monophosphate and ketose monophosphate).
B Hexose diphosphate (I) ⟶ glyceraldehyde phosphoric acid (II) and dihydroxyacetone phosphoric acid (III).
C. (II) and (III) ⟶ phosphoglyceric acid (IV) and glycerophosphoric acid (V).
D. (IV) ⟶ pyruvic acid (VI) and phosphoric acid.
E. (VI) + (V) ⟶ lactic acid (VII) and (II) or (III).
(II) or (III) then reacts again as in C.

$C_6H_{10}O_4(OPO_3H_2)_2$	(I)
$CHO{\cdot}CHOH{\cdot}CH_2OPO_3H_2$	(II)
$CH_2OH{\cdot}CO\ CH_2OPO_3H_2$	(III)
$COOH\ CHOH{\cdot}CH_2OPO_3H_2$	(IV)
$CH_2OH{\cdot}CHOH{\cdot}CH_2OPO_3H_2$	(V)
$CH_3{\cdot}CO{\cdot}COOH$	(VI)
$CH_3{\cdot}CHOH{\cdot}COOH$	(VII)

Space does not permit the giving of the detailed evidence by which this scheme is supported. It may be observed that the effect of fluoride is to inhibit the reaction marked D, whilst the effect of iodoacetic acid is to interfere with reaction E. Thus in presence of fluoride, phosphoglyceric acid and glycerophosphoric acid are accumulated whilst iodoacetic acid brings about the accumulation of pyruvic acid. It will be seen that even if the Embden scheme is substantially correct considerable gaps remain to be bridged. For example, the conversion of phosphoglyceric acid into pyruvic acid and phosphoric acid is not a reaction which can be easily understood without further elucidation.

Glyoxalase and Glutathione.—We will now describe some recent work, which, taken by itself, would seem to indicate that methyl glyoxal and glyoxalase, the enzyme which brings about its conversion to lactic acid, are of real importance in muscle metabolism. It was shown by Dudley (*Biochem. J.*, 1931, **25**, 439) that the enzyme glyoxalase is inhibited by iodoacetic acid, and it was natural to assume that methyl glyoxal was an essential stage in lactic acid formation and that iodoacetic acid inhibited lactic acid formation through its action on glyoxalase. Lohmann (*Biochem. Z.*, 1932, **254**, 332) showed that glyoxalase preparations lost their activity on dialysis, but regained it on addition of glutathione, and concluded that glutathione was the co-enzyme of glyoxalase. Jowett and Quastel (*Biochem. J.*, 1933, **27**, 486), working on the glyoxalase activity of human red blood cells, discovered that this enzyme seemed to disappear on lysis of the erythrocytes and demonstrated that the lysed cells regained their activity on addition of reduced glutathione. They concluded that the loss of activity was due to the dilution of the glutathione present in the cells. Their experiments support Lohmann's conclusions that reduced glutathione is the co-enzyme of glyoxalase and in addition they have brought forward evidence which, they claim, indicates that methyl glyoxal and glutathione combine to form an intermediate compound from which lactic acid is produced.

In an interesting paper, Dickens (*Biochem. J.*, 1933, **27**, 1141) has now shown that the halogenoacetic acids react with reduced glutathione under very similar conditions to those which exist in the living cell according to the equation

$$GSH + CH_2XCOOH \rightarrow GSCH_2COOH + HX$$
$$[X = Cl, Br, or I.]$$

When cysteine is employed instead of glutathione, an analogous reaction takes place and, in this case, it is possible to isolate the resulting compound in the pure condition. As a result of this reaction the active sulphydryl groups are removed. Dickens further found that the velocity of reaction for iodo-, bromo- and chloroacetic acids are approximately in the ratio 15 : 9 : 0·15 and this is in harmony with the efficiency of these compounds in inhibiting muscle activity and glycolysis. Further, glyoxalase systems poisoned by iodoacetic acid are reactivated by the addition of reduced glutathione. It would thus seem that when iodoacetic acid inhibits glyoxalase activity it does not act on the enzyme itself but on the co-enzyme. What does not appear quite certain from Dickens' paper is whether glutathione is the only compound which can act as co-enzyme or whether other compounds bearing

sulphydryl groups may not also be able to perform that function. Dickens also shows that the quantitative aspects of iodoacetic acid poisoning are not inconsistent with the view that glycolysis inhibition depends on glyoxalase inhibition. Meyerhoff, Lohmann and Meyer (*Biochem. Z.*, 1931, **237**, 437) have shown that adenyl pyrophosphate and Mg ions along with inorganic phosphate form the co-enzyme system necessary for the production of lactic acid from carbohydrate by muscle extracts. Lohmann has also shown that an extract dialysed so as to be free from glutathione had no glycolytic activity, but regained it on the addition of this co-enzyme system. Glutathione did not require to be added and this would suggest that the glyoxalase system is not essential for glycolysis. On the other hand Gaddie and Stewart (*J. Physiol.*, 1934), found that hearts, poisoned by iodoacetate, are brought back almost to normal by the addition of reduced glutathione to the perfusing fluid. Although this reaction might be explained as simply a test-tube reaction between glutathione and iodoacetic acid resulting in removal of the latter, nevertheless when it is brought into relation with the other result mentioned above, namely that the anaerobic heart can utilise methyl glyoxal as a source of energy, it is tempting to believe that its significance is greater than the above explanation would assign to it.

The critical question at present unanswered would appear to be whether methyl glyoxal plays an essential part in the process of anaerobic breakdown of glucose or glycogen to lactic acid; as indicated above it seems difficult to bring all the available facts within the scope of one common scheme, and Gaddie and Stewart suggest the possibility that there may be two routes only one of which passes through methyl glyoxal. Though final judgment on this, as on other important points in muscle metabolism, must be suspended it is clear that important advances are being rapidly made and the scheme proposed by Embden co-ordinates many of the new observations and is likely to stimulate much further work in the near future.

GEOLOGY. By G. W. Tyrrell, A.R.C.Sc., D.Sc., The University, Glasgow.

Geology and Petrology of Igneous Rocks. The work by A. Geller entitled "Die Deutung der Gesteinsanalysen auf Grund der Molecularwerte und die petrographische Systematik auf genetischer Grundlage" (*Abt. d. Preuss, Geol. Landesanst., N.F.*, Heft 143, 1932, 58 pp.) is a valuable comparative survey of the genetic bases of classification of igneous rocks and the significance

of rock analyses, as used by Osann, Niggli, Hommel, von Wolff and others in petrogenetic studies.

Calculating the R.I. of the supposed " carnegieite " in anemousite feldspar which Barth has recorded from pacificite (= anemousite-basalt, see SCIENCE PROGRESS, April, 1931, p. 583), D. Beliankin (*C. R. Acad. Sci. U R.S.S.*, 1931, 27–31) finds that the figure is far too high for true carnegieite, and thinks that the presence of this molecule is extremely doubtful. Pacificite, in his view, is simply a basalt with excess of *aluminate*, which must be carried in the pyroxenes as well as in the feldspars

In their paper on " The Changed Composition of an Anorthoclase-bearing Rock-glass," L Hawkes and H. F. Harwood (*Min. Mag.*, XXIII, 1932, 163–74) cite the case of a glassy contact-facies to a felsite dike in which, although the glass shows no trace of alteration, there has been a considerable change of composition involving loss of silica, addition of water, and replacement of potash by soda This change is attributed to the action of products released during the consolidation of the main dike body. These facts render caution necessary in any petrogenetic theory which depends on the view that rock glasses necessarily represent the composition of original magmatic liquids It is safer to take the fine-grained holocrystalline contact rock as a guide to original magmatic composition.

The useful paper by C. K. Wentworth and Howel Williams on " The Classification and Terminology of the Pyroclastic Rocks " (*Bull. Nat. Research Council*, No. 89, Washington, D.C., 1932, 53 pp.) is a contribution to a series dealing with definitions of sedimentary rocks. Recent classifications are reviewed and a glossary of suggested usages of the terms is given.

In his paper " Über die Raumbildung grosser flacher Intrusivlager," F. Loewinson-Lessing (*Min. Petr. Mitt.*, **43**, 1932, 271–82) propounds a new theory of the mode of emplacement of large sills. These intrusive masses are believed to originate by plastic downwardly-directed subsidence of the floor of a potential free space and lateral penetration by the magma without uplift of the roof. Sills are confined to regions of subsidence. Other recent papers on the same and related topics are the following : H. Harrassowitz, " Beobachtungen an Basaltdurchbrüchen " (*Fortschr. d. Geol. u. Pal.*, **11**, Deecke Festschrift, 1932, 25–43) ; W. Klüpfel, " Das Faciesgesetz der vorquartären Vulkaneruptionen. Über die Bedeutung der Flachintrusionen, die Ursachen der Aschen- und Lavaforderung und über Beziehungen zwischen Vulkanismus und Tektonik " (*Geol. Rundsch.*, XXIV, 1933, 28–55. A summary of

this paper appears in *Forsch. u. Fortschr.*, 9 Jahrg., Berlin, 20 Juni, 1933, 2 pp.); K. Hummel, "Oberflächlichennahe Intrusionen und Trümmerlaven in der Südalpinen Mitteltrias" (*Fortschr. d. Geol. u. Pal.*, **11**, Deecke Festschrift, 1932, 44–74).

Dr. W. Q. Kennedy describes a remarkable composite lava flow in the Carboniferous of Renfrewshire (*Summ Prog. Geol. Surv. for 1932—Part II*, 1933, 83–93). Here an extrusion of mugearite during cooling was eviscerated by a flow of trachyandesite which took the place of the still-liquid central part of the earlier lava. It also broke through and partially assimilated the solid margins of the mugearite, producing interesting mixture-rocks.

The problems of batholiths are posed and much valuable information has been accumulated in three reports which have recently come to hand (Report of the Committee on Batholithic Problems appointed by the Board of Geology and Geography of the National Research Council of U.S.A., Washington, 1930. Typescript Circular, 17 pp; *ibid*, 1932, 13 pp, and 1933, 18 pp.). The last report contains a "Summary of Progress on the Batholithic Problem in North America for 1932," by A. F. Buddington, a paper on "Partial Immiscibility of Magmas," by C. N. Fenner, and is accompanied by an elaborate outline of "Problems of the Batholiths" (59 pp.) by the Committee.

In his paper on "Batholiths of Southern Rhodesia," A. M. Macgregor (*Geol. Mag.*, LXIX, 1932, 18–29) clarifies and fixes a distinction between "Suess-batholiths" and "Daly-batholiths," the former term being applied to granitic batholiths in which anatexis has been the dominant process in their emplacement. Daly-batholiths, however, made space for themselves by bodily replacement (displacement ?) of the invaded formation.

W. H. Emmons (*Journ. Geol.*, XLI, 1933, 1–11) deals with the conditions prevailing in the basal regions of granitic batholiths, especially in relation to the concentration of metalliferous deposits in the roof of the intrusion and their almost complete absence from its core.

In continuation of their studies on the Kainozoic ring complexes of north-eastern Ireland J. E. Richey and H. H. Thomas have now described the Slieve Gullion mass (*Quart. Journ. Geol. Soc.*, LXXXVIII, 1932, 776–849). This ring has been intruded in remarkable conformity around the western end of the Newry Granite of Lower Old Red Sandstone age. The association of ring-dike intrusion and volcanic brecciation is well exemplified in Slieve Gullion, and space for the intrusion was obtained, at least partly, by brecciation of the country-rocks.

From study of the chemical composition of late differentiates of basaltic magmas, as shown by "pegmatitoids" and segregation-veins in basalts and dolerites, Dr. W. Q. Kennedy has come to the conclusion (*Amer. Journ Sci.*, XXV, 1933, 239–56) that there exist two primary basaltic magmas, the olivine-basalt type (under-saturated), and the tholeiitic type (oversaturated), each of which normally gives rise to its own particular line of descent. Olivine-basalt magma produces the line trachyandesite-trachyte-phonolite; tholeiite magma the line andesite-rhyolite. Much the same results have been reached by the writer of these notes in an unpublished study, a brief summary of which is to be found in *Nature*, **130,** November 12, 1932, p 745.

The point of view sustained in H. G. Backlund's paper "On the Mode of Intrusion of Deepseated Alkaline Bodies" (*Bull. Geol. Inst. Upsala*, XXIV, 1932, 1–24) may be indicated by the following quotation: "If the granitic intrusions in general may be characteristic of orogenic movements, or the revolution phases (*orogenesis*), and the basaltic ones of epeirogenic movements, or the evolution phases (*epeirogenesis*), the alkaline intrusions piercing through the very stable areas may be a sort of *epeirodiatresis*, a perforation of stable continental areas."

Professor A. Holmes's paper on "The Origin of Igneous Rocks" (*Geol. Mag.*, LXIX, 1932, 543–58) constituted the opening contribution to a discussion on this subject in Section C (Geology) of the British Association at its York Meeting 1932 (see *Nature*, **130,** 1932, p. 745). The genetic problem is shown to lead back by all routes to the more general problem of the composition, arrangement, and thermal condition of the outer crust of the earth. The most important part of the paper concerns a "new key to petrogenesis" which is based on the generation of Ca^{41} from K^{41} and its accumulation during geological time. The ratio of Ca^{41} to Ca should be relatively large if, say, a Tertiary granophyre had been produced by re-fusion of pre-existing granite. On the other hand, the ratio should be much smaller if the acid rock had been a differentiate from basaltic magma.

Dr. A. Brammall's valuable paper on "Syntexis and Differentiation" (*Geol. Mag.*, LXX, 1933, 97–107), which was given in the above-mentioned symposium, is too closely knit, and too packed with data to admit of summary. He believes that the general genetic problem (of igneous rocks) would benefit by being liberated from "the tyranny of the silica percentage." As in his recent Dartmoor work he emphasises the importance of the minor constituents of the rocks in discussing genetic relations.

The chief theme of Dr. S. R. Nockolds's paper on "Some Theoretical Aspects of Contamination in Acid Magmas" (*Journ. Geol.*, XLI. 1933, 561–89) is that contamination is closely connected with the volatiles of the magma, the function of which is to form a medium of low viscosity through which reciprocal diffusion between magma and xenolith can take place. The diffusion so effected establishes mineral phase equilibrium in both xenolith and contaminated magma. Mechanical disintegration of a xenolith may also set free its mineral constituents within the magma.

In a further paper Dr. Nockolds discusses "The Production of Normal Rock-Types by Contamination and their Bearing on Petrogenesis" (*Geol Mag.*, LXXI, 1934, 31 9), the most important cases of which are due to assimilation of basic rock material by acid magma. It is shown that such reactions tend to cause what is here termed "contrasted differentiation," *i.e.* the production of contrasted acid and basic magma types. The high fractionation which is exhibited by the gabbro-granophyre association, for example, is ascribed by Dr. Nockolds to contamination effects.

The recent *Geological Survey Memoir* on "The Geology of the Cheviot Hills" (Expl. of Shs. 3 and 5, 1932, 174 pp.) by R. C. Carruthers, G. A. Burnett, and W. Anderson, with petrological notes by H. H. Thomas, provides a new account of the classic area of Old Red Sandstone andesite lavas of this region. New points are that the central granite shows abundant evidence of contamination by lavas, and that the augite-bearing type of granite characteristic of the Cheviots is always due to the absorption of basic rock.

Detailed descriptions of granite masses which have been modified by contamination and hybridism are the following: J. H. Taylor and E. A. Gamba, "The Oatland (I.O.M.) Igneous Complex," (*Proc. Geol. Assoc.*, XLIV, 1933, 355–76); and S. R. Nockolds, "The Contaminated Granite of Bibette Head, Alderney" (*Geol. Mag.*, LXX, 1932, 433–52).

A specimen from the inaccessible Ve Skerries of Shetland has been found by F. Walker to consist of albitite (*Min. Mag.*, XXIII, 1932, 239–42). Chemical analysis shows its close affinity to similar rocks from the Urals and the Sierra Nevada (Cal.), and to an albite-porphyry from Assynt, Sutherland. Dr. Walker assigns the Shetland rock to the same post-Cambrian igneous activity as the Assynt intrusions.

The Braefoot Outer Sill, Fife, described by R. Campbell, T. C. Day, and A. G. Stenhouse (*Trans. Edin. Geol. Soc.*, XII, Part 4, 1932, 342–75) is a complex composite intrusion. The highest and

lowest members are basalts; between these, from below upwards, occur picroteschenite, teschenites with increasing analcitisation, dolerite-pegmatites, and dolerite Narrow dikes of alkali-microsyenite, similar to the mesostasis of the pegmatites, traverse the pegmatite and overlying parts of the intrusion. The balance of evidence leads to Flett's hypothesis of elutriation of olivine crystals for the origin of the ultrabasic types The dolerite, which approximates to quartz-dolerite in composition, has resulted from acidification of part of the magma by assimilation of quartzose sediments

T. C. Day describes the teschenite of Point Garry, North Berwick (*Trans. Edin Geol Soc* , XII, Part 4, 1932, 334–7) with the aid of three new chemical analyses, in addition to analyses of the bedded ashes into which the teschenite was intruded, and of a sandstone xenolith.

In continuation of his series of papers on borings through Scottish intrusions, Sir J. S. Flett has now described the petrology of the Stankards Sill, near Uphall, West Lothian (*Summ. Prog Geol. Surv. for 1931*, Part II, 1932, 141-56). The sill is 217½ feet thick and consists of essoxite, teschenite, olivine-diabase, picroteschenite, and picrite. A mass of picrite, 123 feet thick, occupies the centre of the sill. It is overlain by essexite, teschenite, and olivine-diabase, and underlain by picroteschenite Sir J. S. Flett thinks that differentiation must have been effected prior to or during intrusion, and that it cannot have been due to crystallisation and precipitation of olivine and augite after injection.

The Old Red Sandstone lavas of Moncrieffe Hill, near Perth, are described by C. F. Davidson (*Geol. Mag.*, LXX, 1932, 452–64) as olivine-enstatite-basalts. Acid andesites and hypabyssal rocks from volcanic conglomerates predating the lavas, and segregation veins rich in analcite and alkali-feldspar, have been recorded.

In his paper on "Volcanic and Other Igneous Rocks of Great and Little Langdale, Westmorland, . . ." Dr. J. J. Hartley (*Proc. Geol. Assoc.*, XLIII, 1932, 32–69) traces the main tectonic features of Ambleside area farther to the west. In the Langdale area there is a large exposure of acid rocks intrusive into metamorphosed tuffs and lavas. Folding and cleavage due to Late Ordovician and Devonian earth movements are fully described.

According to W. G Tidmarsh the Permian lavas of Devonshire comprise basaltic, intermediate, and lamprophyric types (*Quart. Journ. Geol. Soc.*, LXXXVIII, 1932, 712–75). The first two groups are called para-basalts and para-trachyandesites because they are regarded as hybrid products arising as late differentiates of a granodiorite magma. Numerous new analyses are recorded. Many of

the types are unusually rich in potash. The resemblances of these lavas to the Permian basalts of Ayrshire was emphasised in the discussion by Dr. W. Q. Kennedy, who argued against the hypothesis of origin by hybridisation.

The veteran Professor W. C Brögger has now completed his mighty work, begun sixty years ago, on the petrology of the Oslo petrographic province with the publication of his memoir: "Die chemische Zusammensetzung der Eruptivgesteine des Oslogebietes. Die Eruptivgesteine des Oslogebietes, VII" (*Norske Vidensk. -Akad. i Oslo, I. M. -N. Kl*, 1933, No 1, 147 pp.), which was preceded by a memoir: "Ueber verschiedene Ganggesteine des Oslogebietes. Die Eruptivgesteine des Oslogebietes, VI" (*ibid.*, 1932, No. 7, 88 pp). This work brings together no fewer than 331 chemical analyses of the igneous rocks of the Oslo region, the great majority of which are here published for the first time. Comment on this supremely important memoir must be reserved until an opportunity offers for greater length than is afforded by these notes.

R. Norin has made a detailed mineralogical and petrological study of the Kainozoic basalt occurrences of Scania, Sweden (*Geol För. Förh. Stockholm*, **55**, 1933, 101–49). The eight new chemical analyses indicate that most of the rocks belong to a basic type of olivine-trachybasalt

K. Holler has described the regional characteristics of the small basalt region of the Northern Odenwald (*Centr. f. Min., Abt. A.*, 1932, 378–91). It has a considerable range of variation from nepheline-basalt, through monchiquite and haüyn-basalt, to trachyte, which is believed to have arisen partly by processes of differentiation, partly by assimilation and contact-metamorphism.

Professor E. Lehmann has continued his series of memoirs on the Variscian rock and mineral province of the Lahn-Dill region (see SCIENCE PROGRESS, January 1933, p. 434) with a paper on "Das Nebengestein des Eisenerzlagers Theodor bei Aumenau" (*N.J.f. Min., B.-B.*, 67, *Abt. A*, 1933, 69–117) in which he describes a further series of spilites, diabases, and schalsteins, with special reference to the processes of calcitisation and chloritisation which these rocks have undergone. Another paper provides a useful general account of the igneous rocks of the Lahn-Dill region, with analyses of some unusual potash-rich types which he calls keratophyre-spilite ("Ueber 'Diabase' und Schalsteine aus dem Mitteldevon des Lahn-Dillgebiets," *Ber. Oberhess. Ges. f. Natur.-u. Heilkunde*, 2, *Giessen*, **15**, 1933, 307–34).

That part of the teschenite-picrite region of Moravia which lies in Poland has been fully described by K. Smulikowski ("*Kosmos*"

Journ. Soc. Pol. d. Nat. " *Kopernik* ", **54**, Fasc. III–IV, 1929, Sér A. Mem., 1930, pp. 741–8 Polish summary, pp. 749–850 in French) with the aid of several new chemical analyses. Good analyses now exist of picrite, ankaratrite, monchiquite, fourchite, ouachitite, teschenite, dolerite, essexite, nepheline-monzonite, and nepheline-syenite ; but there is still a lack of analyses representing the most abundant and characteristic rock type, *viz.* teschenite. Smulikowski pronounces against the theory of limestone syntexis which was put forward by O. Paçak for the origin of this suite, and explains it by simple crystallisation-differentiation from an original essexite-gabbro (= trachybasaltic) magma.

In his memoir " Ueber die Pyroxenandesite des Cserhátgebirge (Ungarn) " A. Vendl (*Min. u Petr. Mitt.*, **42,** 1932, 491–550) provides some new analyses of Hungarian andesites, and in addition gives a comprehensive discussion of the chemical, provincial, and differentiation relations of the Tertiary igneous fields on the northern border of the Pannonian basin.

The paper by E. Lengyel, I. Finály, and T. Szelényi entitled : " Beiträge zur Petrographie der Hohen Tatra II Die Gesteine des Felkaer Tales." (*Acta Chem Min Phys., Univ Szeged*, Tom. III, 1933, 36 49) gives descriptions and chemical analyses of certain granites, aplites, pegmatites, and contact-rocks E Lengyel (*Föld. Közl.*, Bd. LXII, 1933, 1–10) has further elucidated the petrogenetic aspects of these rocks

The important work by A. Codarcea entitled " Étude géologique et pétrographique de la région Ocna de Fer—Bocsa Montana, Banat, Roumanie " (*Anu Inst. Geol Roum* , XV, 1932, 261–435) contains, beside descriptions of the crystalline basement rocks, the Carboniferous to Mesozoic sediments, and of tectonics, a full description and discussion of the banatite intrusions of the region with their numerous apophyses and associated dike series. Fourteen new analyses are tabulated and there is a discussion of the contact metamorphism effected by these intrusions

The corundum-plagioclasites of Kaslinskaja Datcha in the Urals have been described by J. Sokolov (*Trans. Geol. and Prosp. Serv. of U.S.S.R.*, **56,** 1931, 1–43). The corundiferous types are albitite, oligoclasite, and anorthosite ; but some albitites and amphibole-oligoclasites are free from corundum. These rocks occur as intrusions in serpentine which is associated with a granite and amphibolite rock complex.

Saxonite with narrow bands of dunite is the dominating rock of the Rai-Iz Peridotite Massif in the Arctic Ural, described by A. Savaritsky (? A Monograph, Russian text, pp. 1–170 ; English

summary, pp. 171–200. For digest see *Geol. Zentralbl.*, **49**, 1933, 179–80). The massif is associated with gabbro and amphibolite.

An alkaline igneous complex at C. Turij (Kola Peninsula), which has been previously investigated by Russian and Finnish geologists, has been re-studied by D. Beliankin and V. I. Vlodavec (*Trav. de l'Inst. pétr. de l'Acad. U.R.S.S.*, Livre 2, 1932, 45–71). The rocks occur as dikes which, from their intersections, are grouped in three age series : 1, Monchiquite and alnöite, eruptive breccias, limestones or calcitite , 2, Ijolite, turjaite, melanocratic ægirine-syenite, and various types of calcitite ; 3, Monchiquite, alnoite, augitite, nephelinite, calcitite. A connection with the magmatic focus of the great Chibina nepheline-syenite massif is suggested

An important study of the evolution and differentiation of the Somma-Vesuvius magma has been made by A. Rittmann (*Zeitschr. f. Vulk.*, XV, 1933, 8–94). Desilication of the magma by assimilation of limestone and dolomite took place, resulting in strong differentiation, whilst at the same time there was a parallel enrichment in potash owing to the production of soda-rich minerals by contact metamorphism and auto-pneumatolysis. A summary of this theory is given in *Naturwiss*, April 29, 1932 (see *Nature*, June 11, 1932, p. 873).

A most valuable contribution to chemical petrography has been made by E. Narici (*Zeitschr. f. Vulk.*, XIV, 1934, 210–39 ; and XV, 1933, pp. 93–9) with no fewer than 108 new chemical analyses of the alkaline and leucitic igneous rocks of Procida, the Phlegræan Fields, Somma and Vesuvius, and Monte Vulture.

C. Burri and I. Parga-Pondal have described the main rock-types of the Late-Tertiary to Quaternary lavas of Campos de Calatrava, Ciudad Real, Spain (*Schweiz, Min. u. Petr. Mitt.*, XIII, 1933, 40–73). The types found are olivine-labradorite-basalt, ankaratrite (olivine-nephelinite), melilite-nosean-ankaratrite and melanocratic olivine-leucitites. With the aid of eight new chemical analyses the chemistry and provincial relations of the suite are discussed, and are compared with other fields of late geological date in the Iberian Peninsula.

PEDOLOGY. By Professor N. M. Comber, D.Sc., A.R.C.S., F.I.C., The University, Leeds.

Attention may be drawn to the recent publication of *Methoden für die Untersuchung des Bodens* under the editorship of O. Lemmermann. This is an attempt undertaken on behalf of the German Society for Soil Science and the German Experimental Stations to produce a comprehensive laboratory manual, and it should be of great

value to every one concerned with the laboratory examination of soil.

Humus.—In spite of the long-standing recognition of the importance of humus as a factor in soil fertility and of the part played by it in differentiating the horizons of the soil profile, it is only quite recently that there has been anything like a general consensus of opinion about the chemical nature of humus. The clarification of our ideas is largely due to the work of Waksman and Iyer in America (*Soil Science*, **34**, 43, and **36**, 57) and of Page and his co-workers at Rothamsted (*J. Ag Sci.*, **22**, 115, 291, 297, 497 and 516).

In the early part of the Rothamsted work on humus there accrued considerable evidence that the humus formed from quite different plant residues and under different conditions was similar in its properties and therefore presumably in its composition. For instance, while the percentages of carbon in the alkali extract of dunged and unmanured plots were very different, as would be expected, the amounts expressed as percentages of the total amount present in the untreated soil were all of the same order Moreover, the ratios of carbon in the alkaline extracts to the depths of colour, determined arbitrarily as measures of the amount of humus present, were of the same order. The approximate constancy was maintained not only over the plots of one field but over the plots of both the wheat and mangold fields the unmanured plots of which derive their humus from very different sources of vegetable matter.

It would therefore seem that either the various constituents of such very different kinds of plant residues as wheat straw and mangold leaves can ultimately give the same humic products or else that there is some one constituent or group of constituents which is common to all plants and which is the source of humus. There has long been a suspicion that lignin is involved in humus formation and considerable confirmation of this has come from the Rothamsted experiments. Four different kinds of plant materials were used and the various groups of constituents estimated in the original material and in the product of humification under experimental conditions. The "humification value" was determined by a colorimetric method and the ratio of this to the loss of the various constituents determined. The ratio of humus formed to the amount of constituent lost was not even approximately constant except in the case of lignin. The ratio varied from 3 to 20 for celluloses and from 2·5 to 30 for the furfuroids, but the variation was only between 2·0 and 2·8 for the lignins except in one case in which it rose to 4. Considering the errors of the experimental determination, this is strong evidence that lignin is a parent material of humus.

The Nitrogen of Humus.—There has been a great conflict of opinion as to whether the small percentage of nitrogen in humus is an essential part of the chemical structure of humus or whether it is present in what is more properly regarded as an adventitious "impurity." The issue was for long confused by the general supposition that the black products of such reactions as those ensuing between sugars and mineral acids, and which obviously contain no nitrogen, were akin to soil humus. The abandonment of this view has removed considerable prejudice from the enquiry into the relation of the nitrogen to the humus molecule and it is now generally conceded that the nitrogen is an essential element. The Rothamsted workers in a long series of experiments tried various means of removing any adventitious substances from humus—many reprecipitations, ultrafiltration, dialysis, salting out and other processes—but failed to reduce the percentage of nitrogen by any considerable amount. They showed, moreover, that the percentages of nitrogen in various alkaline extracts of humus-containing soils are approximately proportional to the percentages of carbon

By the application of the van Slyke method it was shown at Rothamsted that the distribution of the nitrogen in the products of hydrolysis of humus was similar to the distribution in the hydrolysates of protein and this led to the revival of a view put forward by Dehérain over forty years ago that humus is a mixture or combination of lignin and protein This view has also been revived independently by Waksman. One objection to the view that humus nitrogen is in a protein combination was the fact that proteins are readily attacked by soil micro-organisms while humus is manifestly resistant. In the first of their series of papers, however, Waksman and Iyer show that lignin has an inhibiting effect on the decomposition of proteins by micro-organisms both *in vitro* and in soil and under both acid and alkaline conditions. They show, too, that the greater the amount of lignin associated with the protein, the greater is the inhibiting effect. The effect is also greater the more intimately the lignin is associated with the protein. After the mixture has been heated the protein is more resistant than after mere mixing in the cold, and it is very much more resistant after the protein and lignin have been mutually precipitated from an alkaline solution. It is concluded that there is a chemical combination of lignin from plant residues and protein synthesised by micro-organisms with the formation of a ligno-protein.

It is interesting to note that lignin has no inhibiting effect upon the decomposition of peptone and amino-acids—indeed the attack of organisms on glycocoll seems to be expedited.

Waksman and Iyer compared synthetic ligno-proteins with the humus extracted from soil by alkali and precipitated by acid, in a number of ways—solubility in various solvents, oxidation by hydrogen peroxide, acetyl bromide, etc.—and showed a general similarity. That no such similarity exists between soil humus and such products (formerly considered as artificial humus) as those formed by the action of acid on sugar had already been shown at Rothamsted.

In view of the general belief that one important function of humus in soil is the stimulation of the growth and action of micro-organisms, it is to be noted that the synthetic products in alkaline reaction had a marked effect upon the microbial decomposition of glucose, particularly when an appropriate inorganic nitrogen compound was added.

There has for some time been considerable evidence that the base exchange capacity of humus is considerably greater than that of clay, and Waksman and Iyer have shown that their synthetic ligno-proteins have a high base exchange capacity which is much greater than the added base exchange capacities of the protein and the lignin Thus a precipitated ligno-gliadin had an exchange capacity between six and seven times the added capacities of the lignin and the gliadin.

Soil Profiles.—An interesting study has been made by A. B Stewart (*J Ag. Sci.*, **23**, 73) on the profile of an area of virgin soil near Aberdeen and the profile of a neighbouring cultivated area Scope for this kind of comparison and facilities for studying the effects of cultivation are very rare in this country. The virgin land was definitely podsolised, while the cultivated soil was more akin to a brown earth with, however, some signs of podsolisation, and the evidence does indicate that the effect of cultivation on a podsol will lead to " regradation " of this kind.

Doyne and Watson (*J Ag. Sci.*, **23**, 208) describe a typical profile of south-western Nigeria. A brown sandy soil is underlain by a layer with concretions while under that is a red clay. The chief point arising from this study is the conclusion that iron *rises* during periods of evaporation and is deposited on silica in the second layer forming the concretions. Little or no aluminium accompanies the iron which is thought to move in colloidal solution.

Rapid Examination of Soils.—Schofield (*J. Ag. Sci.*, **22**, 135) has put forward a new method for the quick examination of the heaviness of a soil. The " rolling weight " (W) is essentially the weight under which a cylinder of the soil at its most plastic water content begins to flatten and is a useful measure of heaviness. The apparatus devised for its determination admits of a reading being

taken in a very few minutes. The apparatus is simple and the measurement has none of the unfortunate arbitrariness that detracts from the value of so many soil determinations. The "W" values have been shown to be very definitely correlated with draw-bar pull in a field survey, and for soils of the same type it is closely related to the clay content

Schofield (*J. Ag Sci*, **23,** 252) also publishes a rapid method for determining the amount of lime a soil must take up in order to attain a certain *p*H If a solution of an organic acid with (say) half the amount of lime required to neutralise it is brought into contact with a soil, the soil will attain the *p*H of the solution either giving up some lime to the solution or removing some from it. The *p*H will not change to any extent that matters if the amount of lime passing between soil and solution is not too great, and the amount of lime taken up by an acid soil can be taken as a measure of the lime needed to bring the soil to that *p*H. This principle has been applied to the use of a solution of lime and *p*-nitrophenol. The method is simple and rapid and by applying it to the acid-washed soil as well as the original soil the total exchangeable base can be determined.

The determination of the base exchange capacity of a soil by the reduction in conductivity of a solution of di- and mono-potassium phosphate caused by the soil has also been explored by Schofield (*J. Ag. Sci.*, **23,** 255).

BOTANY. By PROFESSOR E. J SALISBURY, D.Sc., F.R.S., University College, London.

ECOLOGICAL.—In an interesting paper by Blum (*Bull. d. Soc Bot. Suisse*, B, 42 h., 550–680, 1933) data are furnished regarding osmotic phenomena in Java. Experiments on the Dilleniaceous shrub *Wormia suffruticosa* showed a minimum suction force in the morning rising to a maximum at mid-day, the changes being approximately parallel to changes in the saturation deficit in the air. The suction force of individual cells ranged from 8·9 to 13·5 atmospheres for the lower epidermis and from 42·5 to 46·9 for the palisade layer. Comparisons of epiphytic and terrestrial orchids showed a similar daily periodicity. The suction force of the leaves of Dicotyledonous trees ranged from 4·7 to 32·1 atms.: of the lianes from 10·4 to 39·8 atms. and of the herbs from 5·4 to 17·8 atms. Epiphytic orchids developed suction forces from 1·3 to 32·1 atms. and epiphytic ferns from 4·0 to 25·5, whilst terrestrial orchids developed from 6·7 to 13·5 and terrestrial ferns from 11·9 to 34·6 atms. Measurements made in primeval forest showed a relative humidity of from

90 per cent. to 98 per cent. and a saturation deficit of only 0·25 to 1·7 per cent. even during a dry period. It is therefore scarcely surprising that the data during rainfall showed but slightly higher humidities and lower saturation deficits. Even in a clearing the humidity did not fall below 60 per cent. in dry weather. Determinations of suction force in the leaves of the natural forest vegetation showed an increase in the maximum values observed for the successive tiers, as one passes from below upwards. The epiphytes which develop water storage tissue exhibit lower values than those without In general the leaf tissues showed an increasing suction force in the following order : water-storage tissue , lower epidermis , upper epidermis ; spongy parenchyma ; palisade tissue. These results would then appear to indicate the water storage function of the epidermis and that the suction force tends to augment as the humidity of the environment diminishes whether in space or time.

In the same journal Ursprung shows that the osmotic pressure varies with the water balance, a deficit causing a rise and vice versa.

The seasonal changes in the osmotic pressure of a number of species has been investigated by R. Thren (*Zeit. fur Bot.* B, 26 H, 9/10, 1934). In *Picea* the highest values were recorded at the end of January (27·5 atms.) and the lowest in June. *Pinus sylvestris* exhibited parallel changes with a minimum of 15·7 atms. and a maximum of 22·5 atms. Beech leaves showed a maximum value in August (*c.* 24 atms.) and a minimum in April (*c.* 15 atms). For Heather the maximum was in December (37·6 atms.) and the minimum in August (10·4 atms.) whilst Whortleberry showed a minimum in May (14·7 atms.) and two periods of high osmotic pressure in March and October (up to 26·9 atms.) The woodland herbs *Digitalis* and *Teucrium scorodonia* both showed minima in May of about 8 atms. and maxima in March of about 25 atms. The succulent Sedums appear to attain their highest values in spring and their lowest in summer. The prevernal geophytes represented by *Adoxa* and *Ficaria* yielded similar values in the early spring (*c.* 11 atms.) and a marked decrease following the development of the tree foliage when the osmotic pressure falls to about seven atmospheres. Here too the changes appear to be correlated with the fluctuations in the water balance.

Narasimhan in 1918 and Mcluckie in 1932 showed that the coralloid roots of *Casuarina* contained nitrogen-fixing bacteria. H. Mowry in a recent paper (*Soil Science*, XXVI, 409, Dec. 1933) has investigated further this relationship by means of sand cultures of several species grown both inoculated and uninoculated, also

with and without nitrates in the culture solution. All species grew quite well in the absence of nitrates when inoculated by bacteria, but failed to do so when not inoculated. Nevertheless, even in the absence of inoculation good growth resulted when nitrates were supplied. Nine species were all successfully inoculated with the same strain, suggesting the absence of biological races such as are commonly found in the Leguminosæ. The Casuarinas in Florida occur on soils with a wide range of reaction (P_H 5·2 to 7·8) and attention is drawn to their value for colonising sand dunes and other soils poor in nitrogen and acid in reaction.

In the same journal J. B. Hestor reports the results of the flooding of large areas of cultivated land by sea-water in Virginia, from which it appears that the higher the organic content of the soil the greater is the concentration of sodium chloride which plants can tolerate. Cultures of Strawberry plants showed that 0·2 per cent. was fatal on sandy soil with only 3 per cent. of organic material, whereas injury only resulted from 0·46 per cent. of sodium chloride when the organic content was approximately 8 per cent.

Vegetative propagation in *Drosera* has been known for some time, but some interesting details are furnished by J. W. Vickery (*Proc. Linn. Soc. N.S.W*, LVIII, 245–69, 1933) respecting two tuber-forming species from Australia, *viz. D. peltata* and *D. auriculata*. The tubers develop from axillary buds in both. After germination the seedling produces an axillary bud at its base which grows down into the soil and the end of this swells up, giving rise to a buried tuber. Such a "dropper" development continues each year until the appropriate level is attained, when further descent of the tuber ceases. Evidence is afforded to indicate that soil texture is relatively unimportant, compared with soil-moisture, in determining the equilibrium level of the tubers. In drier types of soil this level is commonly about 5 cm. whilst in moist soils the average depth may not be more than three centimetres, but in light dry sand tubers were found at 10 cm. Vegetative multiplication by epiphyllous buds, such as occurs in the British Sundews, was observed in *D. auriculata, D. peltata, D. spathulata, D. arcturi* and *D. binata*, so that it would seem to be a characteristic of the genus as a whole.

From a study of four species of *Cistus*, Chodat (*Bull. d. Soc. Bot. Suisse*, p. 507, 1933) finds that the most calcicole species contains the greatest amount of calcium and the least amount of silica whilst the reverse is the case for the calcifuge species. Further, this relation obtains when the species are grown side by side in the same soil. Thus the calcicole *C. albidus* yielded an

ash containing nearly 32 per cent. of CaO and 22 per cent. SiO_2 whereas the ash of the calcifuge *C. salvifolius* contained only about 16 per cent. of calcium and nearly 50 per cent. of silica.

The relative palatability for grazing stock of miscellaneous herbs is the subject of a paper by W. E. J. Milton in the *Empire Jour. Exp. Agr.*, I, 347, 1933. Of species abundant in lowland grasslands the Ribwort (*P. lanceolata*) and the Daisy are notable as being extensively grazed whereas the Selfheal (*Prunella*) and the Yarrow (*Achillea*) are only eaten to a slight extent. In corn stubble the following species, though present in appreciable amount, appear to be avoided . *Alchemilla arvensis*, *Sagina procumbens*, *Cerastium vulgare*, *Galium verum*, *Anagallis arvensis*, and *Potentilla anserina* In the open hill pastures *Triodia decumbens* is freely eaten as also are *Juncus squarrosus*, *Luzula campestris* and *Carex spp.* *Nardus stricta* though very abundant is probably grazed only as regards the newly developed foliage

Pteridosperms.—Two important papers have appeared recently dealing with plants of presumed Pteridosperm affinity. The first of these by H. Hamshaw Thomas (*Phil. Trans Roy. Soc.*, B, **222**, 193–265) describes plant materials from South Africa of Mesozoic age. These are referred to a new group termed the Corystospermaceæ of which three genera are recognised containing eleven species in all. They are characterised by branched unisexual reproductive shoots which in the female consisted of numerous solitary seeds each enclosed in a cupule and terminating a short branch arising in the axil of a scale-like bract. Male inflorescences, of which eight species are recognised, bore tufts of sporangia at the end of each branch, comparable in general character with a *Crossotheca*, but each of the numerous sporangia contained winged spores similar to those found in the Caytoniales. The second paper by Professor Halle is also the basis of a new group termed the Whittleseyinæ, and describes a number of fructifications some of which have hitherto been regarded as seeds but which Professor Halle, by the use of a modification of Dr. Thomas's technique, has been able to show are in reality synangia containing numerous spores that are probably microspores and perhaps represent the male reproductive organs of members of the Medulloseæ. In the genus *Goldenbergia* a branched axis bore a number of synangia, each terminating one of the ultimate branches and consisting of an oval structure the thick wall of which was formed from the lateral fusion of some twelve elongated sporangia. In *Aulacotheca* a similar structure was present but the synangium was much more elongated and contained about nine sporangia. In the genus

Whittlesya the constituent synangia were very numerous and formed a wineglass-like structure open at the apex. In *Dolerotheca* there were also numerous sporangia, but, instead of these forming a single synangial cylinder, they are borne as a capitulum-like head embedded in sterile tissue. *Potoniea* is similar in organisation but the sporangia were not united and arise as independent structures from the base of a cup of sterile tissue, perhaps accompanied by sterile hairs. *Zeilleria*, thought to have been a seed, is shown to have been a hollow synangium of four to six sporangia but is not regarded as closely related to *Whittlesya* which it somewhat resembles

CYTOLOGY.—Wanscher records the chromosome numbers of fifty additional members of the Umbelliferæ (*Bot Tids.* B, 42 h. 4) and these together with others previously recorded show eleven to be the most frequent haploid number (71 out of 132 species) and eight to be the next most frequent (22 species). The range in haploid number is wide, namely from six to forty-eight. It is of interest to note that *Garrya elliptica*, formerly placed in the Cornaceæ, has a haploid number eleven which agrees not only with *Cornus alba* but also with the number most characteristic of the Umbelliferæ.

PLANT PHYSIOLOGY. By PROFESSOR WALTER STILES, Sc.D., F.R.S., The University, Birmingham.

PHOTOSYNTHESIS.—One of the most interesting contributions of recent years to our knowledge of this subject is the work of G. E. Briggs on induction in photosynthesis, forming the twenty-first of the Experimental Researches on Vegetable Assimilation and Respiration conducted in the Cambridge Botany School ("Induction Phases in Photosynthesis and their Bearing on the Mechanism of the Process," *Proc. Roy. Soc.* B, **113**, 1–41, 1933). It appears from this work that after a green plant is maintained in the dark for a period of two hours or longer and is then exposed to light, there is a definite induction period during which the rate of oxygen evolution from the assimilating tissues increases, and in some cases the final constant rate of photosynthesis for the conditions of an experiment had not been reached in two hours. On comparing experiments made at different temperatures and with different conditions of lighting, it would seem that the ratio of the initial to the final rate increases with rising temperature up to about 25° C., while it also increases with falling light intensity, although there is so much variability among the results with different samples of material that these relations are not very obvious. From a consideration of the experimental data obtained in his experiments Briggs hypothesises a scheme of reactions in the photosynthetic

process. According to this scheme a complex of some substance S, possibly chlorophyll, and carbon dioxide is converted to a substance S_t by the absorption of light energy. This latter substance is then broken down by a catalyst B to give carbohydrate and oxygen, or, alternatively, it may decompose an inhibitor formed in the cell and which combines with the catalyst The data are treated mathematically on the basis of the scheme and it is shown that not only Briggs's own observations, but those of Paauw, Osterhout and Haas, and Warburg agree with the proposed scheme

A number of important researches on photosynthesis have recently appeared from R. H. Dastur's laboratory at Bombay In a paper by R. H Dastur and R. D. Asana ("Effect of Plane-polarised Light on the Formation of Carbohydrate in Leaves," *Ann. Bot*, **46,** 879–91, 1932) experiments are described in which the production of carbohydrates in leaves of *Helianthus annuus* and *Allium cepa* in polarised and non-polarised artificial light was examined, the results being treated statistically. It was found that there was no significant difference in the quantity of carbohydrate produced in polarised and non-polarised light, provided light of the same intensity and spectral composition was employed in the two cases. On repeating the experiments with *Helianthus annuus* and *Raphanus sativus* using sunlight, a similar result was obtained.

A paper by R. H. Dastur and J. J. Chinoy ("Carbon dioxide Assimilation of the Leaves of the Rice Plant, *Oryza sativa* L." *Indian Journ. Agric. Sci.*, **2,** 431–54, 1932) provides the first collected data with regard to the photosynthesis of this important crop plant. The rate of photosynthesis of the leaves was measured in two ways, by determining the rate of absorption of carbon dioxide, and by estimating the carbohydrate produced, and a series of measurements was made over a period of more than three months. The results obtained by the two methods agree in indicating that the photosynthetic activity of the leaves, expressed as rate of assimilation per unit area of leaf surface, increases as the season advances, with a comparatively low maximum at about the third week in August and a second and higher maximum in October, after which the activity of the leaves falls comparatively rapidly.

The interaction of external and internal factors in photosynthesis has been examined by R. H. Dastur and B. L. Desai in the case of some tropical plants ("The Relation between Water-content, Chlorophyll-content and the Rate of Photosynthesis in some Tropical Plants at Different Temperatures," *Ann. Bot.*, **47,** 69–88, 1933). The species employed for this work were *Abutilon asiaticum* G. Don, *Ricinus communis* L. and *Helianthus annuus* L. The authors

conclude from their results that the rate of photosynthesis in these plants is much more closely related to water content than to chlorophyll content. As the temperature increases, the rate of photosynthesis per unit of water content also rises up to a certain temperature above which the rate falls, but no such regularity could be found when the rate was calculated per unit of chlorophyll. The maximum rates of photosynthesis were observed at 34°, 36° and 36° C. in *Abutilon asiaticum*, *Ricinus communis* and *Helianthus annuus* respectively. Actually, the highest rates of photosynthesis observed in these three species were respectively 44, 54 and 106 mg. carbon dioxide per square decimetre of leaf surface per hour. The last mentioned is the highest rate of photosynthesis so far observed, the highest rate previously recorded being that of Willstätter and Stoll for the same species at 25° C. of 80 mg. carbon dioxide per square decimetre per hour. The sunflower thus still holds the record as the most rapidly photosynthesising plant of those examined.

In determining the chlorophyll content of the leaves a method was used previously devised by R. H. Dastur and N. A. Buhariwalla ("Chlorophyll from Tropical Plants and its Quantitative Determination by means of the Spectrograph," *Ann. Bot.*, **42**, 949–64, 1928). By this method the chlorophyll content of a single leaf can be determined, and the authors showed there is a certain degree of correspondence between the water content and chlorophyll content of the leaves. As the leaf grows older both water content and chlorophyll content rise and, after reaching a maximum, fall, but the decline in the value of the water content is much greater than that of the chlorophyll content.

In yet another paper R. H. Dastur and K. M. Samant have examined the different effect of natural and artificial light on photosynthesis ("Study of the Products of Photosynthesis in Leaves in Artificial and in Natural Light," *Ann. Bot.*, **47**, 295–304, 1933). In this investigation the species used were *Abutilon asiaticum*, *Ricinus communis*, *Phaseolus vulgaris* and a small leaved variety of *Helianthus annuus*. Artificial light was provided by a 1500 watt electric lamp, while natural illumination was that of diffuse sunlight. When the intensity of illumination, as measured by a thermopile, was the same with the two sources of light, the amount of carbohydrate formed was different in the two cases. Thus with *Abutilon asiaticum*, the production of total sugars, calculated as hexoses, was 40 to 120 per cent. higher in the plants exposed to diffuse daylight than in those exposed to artificial light, while the starch production was 170 to 290 per cent. higher. In experiments where

the intensities of illumination from the two sources of light were different, the differences in the quantity and proportions of the carbohydrates produced could not be explained as due to the differences in light intensity. It must thus be concluded that the different effects of artificial and natural illumination are related to the composition of the respective lights.

The relation between photosynthetic activity of whole young wheat plants and environmental factors has been investigated by W. H. Hoover, E. S. Johnston and F. E. Brackett ("Carbon Dioxide Assimilation in a Higher Plant," *Smithsonian Misc. Coll.*, **87**, 1-19, 1933). With high light intensity the relationship between rate of photosynthesis and carbon dioxide concentration is linear over a limited range of concentrations, while with high carbon dioxide concentration the relation between rate of photosynthesis and light intensity is also linear over a small range. The transition from the condition in which carbon dioxide is the limiting factor to that where light is limiting occupies a wider range in higher plants than in algæ, a result which is attributed to the variation in both carbon dioxide concentration and light intensity within the leaf.

H. F. Clements (" Mannose and the first sugar of photosynthesis," *Plant Physiol.*, **7**, 547–50, 1932) has examined the leaves of 42 species for mannose and has found it uniformly absent. Since in alkaline solutions mannose and fructose arise together from glucose, the author concludes that the fructose in the leaf does not arise from glucose; but that the glucose and fructose arise together as the first sugars of photosynthesis.

An attempt has been made by R. Emerson and W. Arnold (" A separation of the reactions in photosynthesis by means of intermittent lights, "*Journ. Gen. Physiol.*, **15**, 391–420, 1932) by the use of intermittent illumination to separate the photochemical and dark (" Blackman ") reactions of the photosynthetic process. These two reactions are characterised by their relation to temperature; the Blackman reaction, being an enzymatic or purely chemical reaction, is much more influenced by temperature than the photochemical reaction. From their experiments with *Chlorella* the authors conclude that at 25° C. the Blackman reaction requires less than 0·04 second for its completion, but about 0·4 second at 1·1° C. The photochemical reaction, they conclude, can take place in about 0·00001 second.

Lastly, some recent papers dealing with chlorophyll may be mentioned. V. N. Lubimenko and E. R. Hubbenet, using a spectrocolorimetric method, have followed the development of chlorophyll in etiolated wheat seedlings (" The Influence of Temperature on

the rate of Accumulation of Chlorophyll in Etiolated Seedlings," *New Phyt.*, **31**, 26–57, 1932). The minimum temperature for chlorophyll development is 2° to 4° C., the optimum is given as 26° C. to 30° C., and the maximum as about 48° C. The time taken for the development of the maximum quantity of chlorophyll decreases with increase in temperature from the minimum to the optimum. Above the latter temperature the development of chlorophyll falls off.

An improved standard for the colorimetric estimation of chlorophyll has been proposed by H. B. Sprague and L. B. Troxler ("An improved Color Standard for the Colorimetric Determination of Chlorophyll," *Science*, **71**, 666–7, 1930). It is an aqueous solution containing definite concentrations of malachite green and naphthol yellow.

In two papers A. Stoll and E. Wiedemann record the results of chemical investigations which lead them to propose new formulæ for chlorophyll *a* and *b* ("Über den Reaktionsverlauf der Phasenprobe und die Konstitution von Chlorophyll *a* und *b*," *Helvetica chim. acta*, **15**, 1128–36, 1932; "Über die Konstitution des Chlorophylls und die Bildung der ihm zu Grunde liegenden Dicarbonsäuren," *ibid.*, **15**, 1280–5, 1932). The chief feature of these new formulæ is that the magnesium of the chlorophyll molecules is connected to the four nitrogen atoms each one of which forms part of a five-atom ring, the other four atoms of each ring being carbon. In chlorophyll *a* there is a fifth five-atom ring of carbon atoms in this complex, but in chlorophyll *b* this ring has been opened.

ZOOLOGY.

By G. R. de Beer, M.A., D.Sc.; E. B. Ford, M.A., B.Sc.; J. A. Moy-Thomas, B.A.; B. W. Tucker, M.A.; and J. Z. Young, M.A.; the University, Oxford.

General.—P. R. Lowe (*Proc. Zool. Soc.*, 1933, 483–538) has published an important contribution to knowledge of the morphology of the Penguins, on which he bases some surprising deductions as to the phylogeny of this group. The view usually held as to the systematic position of the Penguins is that they are Carinate or Neognathine birds which have given up the power of flight in favour of an aquatic habit and have become highly specialised and in some respects degenerate in correlation with this mode of life. Dr. Lowe on the other hand maintains that most of the so-called degenerate features are really extremely primitive.

The microscopic structure of the feathers recalls the early developmental stages of the feathers of flying birds and is less suggestive of degeneracy than of a generalised or primitive con-

dition with certain specialisations superimposed. In Carinate birds the major and median under wing-coverts differ from the other feathers of the ventral aspect of the wing in that their " under " surfaces are directed ventrally instead of dorsally, this condition being due to the fact that they really belong to the dorsal aspect of the wing and shift round to the ventral side in early development. In Penguins, however, Lowe shows that the corresponding feathers remain on the dorsal surface of the wing as in the embryos of other birds.

Remarkable features of the moult are described for the first time. The new feathers are fully formed before they erupt, in deep, thick-walled follicles under the skin. The tip of the new feather pushes up into the inferior umbilicus of the old one, with the rim of which the delicate covering sheath of the former is continuous, and when this sheath disintegrates the old feather is detached.

As a result of a re-study of the fossil material the author concludes that the widely held belief that the tarso-metatarsus of early Tertiary penguins approached more closely to that of typical Carinate birds than do the modern forms is erroneous . there is in fact no essential difference. He also considers, in opposition to Pycraft and others, that the embryological development of the Penguin's fore-limb affords no evidence of derivation from a previous volant phase, and he finds characters which appear to be primitive in the musculature and other parts of the anatomy.

The conclusion drawn from these researches is that the Penguins represent a primitively aquatic branch of the avian stock derived from forms which had never acquired the power of flight. While a discussion would be out of place here it may be said that in this connection insufficient weight seems to have been allowed to the many close anatomical and osteological agreements between Penguins and typical carinate birds, which on the above theory would all have to be attributed to convergence, and it may be observed that practically all the characters mentioned would be just as plausibly explained as due to retarded development as to real primitiveness.

C. W. Parsons has studied the development of the same group of birds as illustrated by Pygoscelis embryos collected on the *Discovery* expeditions and has published an account which supplements previous descriptions in a few respects (*Discovery Reports*, **6**, 1932, 139–64). One of the most interesting points which the author emphasises is the early appearance of the special penguin characters. " The embryos are obviously penguins after probably one-third of

the incubation period." In general the developmental stages agree closely with those of the Fowl and have nothing particularly archaic about them. The very rapid rate of growth of the fore-limbs, as soon as the cartilages appear, and their early completion of development is extremely striking, but the early maturing of these important locomotor organs need not altogether surprise us, and we cannot share the author's view that it affords any evidence for the derivation of birds from aquatic reptiles!

An unusual case of the assumption of female characters by a Brown Leghorn cock which was castrated when 51 days old is described by Greenwood and Blyth (*Journ. Genetics*, **26**, 1932, 199–213). The assumption of male characters by female birds whose ovaries have been destroyed by disease or operation or atrophied in old age is well known, but the reverse modification of the male towards the female type is highly abnormal. The change seems to have been correlated with a small tumour situated behind the normal gonad site, but its significance and correct interpretation in connection with the general phenomena of sex in birds are far from clear. The presence of female secondary sexual characters is normally rigidly dependent on the possession of a female gonad, yet in this bird they were exhibited in the absence of any gonad at all. The authors consider that owing to some abnormal condition the tumour, which they believe to have been of gonadic origin, must have been secreting female hormone, but they also believe it must have produced some male hormone at the same time, since the comb showed marked growth, and recent work is held to indicate that comb growth (whether of male or female type) is dependent on male hormone, which is produced in limited quantities in the female, as well as in the male. It is clear, however, that these extremely rare cases of a male-to-female change in birds (only one previous instance is described) are much less well understood than the reverse modification.

Recent researches in America have demonstrated that the injection of mammalian male hormone into castrated cocks and hens induces growth of comb and wattles (McGee, Juhn and Domm, *Amer. Journ. Physiol*, **87**, 1928, 406–35), while injections of female hormone of human origin induces female plumage (Juhn and Gustavson, *Journ. Expt. Zool.*, **56**, 1930, 31–50). These results (which it may be observed in parenthesis are important (*a*) as demonstrating that sex hormones in vertebrates are not even class specific, and (*b*) as inimical to Crew's hypothesis of plumage control in birds by merely quantitative differences in "physiological load" in the two sexes) have been utilised by Lillie and Juhn in a study

of the hormonic control of feather pattern (*Physiol Zool*, **5**, 1932, 124–84).

The effects of injection of thyroxin and female hormone were studied, the latter producing female characters, while the former causes melanin deposition and other changes of a non-sexual character in the neck and saddle feathers. The method is to pluck certain areas and to observe the effect of hormone injections on the regenerating feathers As a preliminary to the experimental work the authors re-studied the development of the feather, and their account differs from the classical descriptions of Davies and Strong in certain respects, for which reference must be made to the original paper.

The rate of growth of the feather barbs is greater at their apex than at the base, and the threshold of reaction to the hormone is proportional to the growth-rate. Since the hormone is quickly excreted from the system unless renewed, a single injection or several in succession at not too long intervals produce a bar across the feather, but this will only extend to the margin if the dosage is above the threshold for the fast-growing apical portions of the barbs. Lower doses produce axial patterns—i.e confined to the bases of the barbs. It is also shown that the rapidity of response to the hormone is greater in fast than in slow growing regions. Hence a dosage of sufficiently high concentration, but acting for only a very short time, may produce positive changes at the margin of the feather, the effects wearing off before the more proximal portions of the barbs have had time to react. These results give promise of a much fuller understanding of the mode of development of feather patterns in general, and they also suggest that the puzzling bilaterally gynandromorph feathers which have been described in (*e.g.*) Bond's gynandromorph pheasant (*Journ. Genetics*, **3**, 1913, 205) can be explained in terms of difference of growth rate on the two sides of the feather, though the genetic basis of such a difference remains obscure.

Embryology.—An outstanding achievement in this field of research has been the preparation from amphibian embryos by Waddington, Needham and Needham (*Nature*, **132**, 1933, 23) of cell-free fluid extracts which possess the property of "organising": *i.e.*, which induce the formation of a secondary embryo. By this discovery, the physico-chemical analysis of Spemann's organiser has been advanced an important step, and the authors are further of the opinion that the active substance is of lipoidal nature.

Further results of great interest bearing on the above, are

reported by Holtfreter (*Naturwiss*, **21**, 1933, 766) who has investigated the range of physical conditions within which the organising substance remains active, and its distribution throughout the living realm. A fact of considerable importance is that whereas in the live state, only the so-called organiser-region of the amphibian embryo possesses organising properties, practically *all* regions of all forms studied (ranging from Annelid worms to man) are capable of organising when killed and grafted into an amphibian embryo. No organising capacities have been demonstrated in vegetable tissues.

In addition to the above, Holtfreter has during the past year published no less than 5 papers (*Arch Entw.mech.*, **129**, 1933, 669, *Biol. Zentralbl.*, **53**, 1933, 404) dealing with the analysis of the morphogenetic processes of organiser-action, and with the self-differentiating powers of the various regions of the amphibian embryo. Thus, he has been able to show (*Arch Entw.mech.*, **127**, 1933, 591) that the induction of a neural tube is to be ascribed solely to the action of the organiser, and not to any properties of so-called " dynamic determination " such as have been ascribed to the movements which the various regions have to undergo.

Next (*Arch. Entw.mech.*, **127**, 1933, 619), he has demonstrated the existence throughout the body of the amphibian embryo (neurula stage) of a number of regional organising influences, proceeding from different tissues, and capable of inducing the formation out of indifferent tissues of structures characteristic of the region in question. In another paper (*Arch. Entw.mech.*, **128**, 1933, 584), Holtfreter gives details of the experiments on the properties of killed organisers, but perhaps the most remarkable of this astonishing series are the experiments (*Arch. Entw.mech.*, **129**, 1933, 669; *Biol. Zentralbl.*, **53**, 1933, 404) on exogastrulation. By simple means, he was able to cause axolotl eggs to undergo evagination instead of invagination of the endoderm and mesoderm, and found that whereas the ectoderm did not differentiate at all, the endoderm and mesoderm developed extremely well by self-differentiation and produced all the non-ectodermal parts of an embryo, inside-out. Further, in those cases where the exogastrulation was only partial and some small portion of the endo-mesoderm became invaginated, Holtfreter was able to observe the progressive organising capacities of increasing amounts of invaginated organiser-region.

The theory of axial gradients has received further support from work by Child (*Sci. Rep. Tohoku Imp. Univ. Biol.*, **8**, 1933, 75) on *Haliclystus*. Regeneration experiments show that apical (distal) regions effectively inhibit growth and differentiation of

more proximal regions (thus confirming Child's views regarding the physiological dominance of apical regions), and reconstitution is found to involve reorganisation of the existing proximal (basal) tissues, thus providing yet another demonstration of the identity of the processes involved in the morphogenetic effects of an organiser and of an apical region of an axial gradient.

The problem of the correlation between the point of sperm-entry, the grey crescent, and the plane of bilateral symmetry in the frog's egg has been reinvestigated by Ti-Chow Tung (*Arch de Biol.*, **44**, 1933, 809) Like Jenkinson, he finds the correlation between these planes to be high, but the results of fertilising experimentally in a selected meridian lead Tung to believe that the correlation is due to a pre-existing bilaterality of the unfertilised egg, which favours sperm-entry at or near the ventral meridian.

In the course of her experiments on tissue-culture of pieces of embryonic chick skeleton, Miss Fell (*Proc. Roy Soc* B, **112**, 1933, 417) has observed that the cells which migrate out from an implant of pure endosteal bone, are capable of differentiating into cartilage, always of the hypertrophic type with little matrix and thin cell-capsules. Further, in older cultures, it was observed that this cartilage turned into bone by the direct transformation of the chondroblasts into osteoblasts. In fact, it seems to be a result of environmental conditions whether these cells give rise to hypertrophic cartilage or to bone. This behaviour is, of course, quite different from the accepted view as to what happens in normal histogenesis of bone, such as occurs in the long bones. Here, the cartilage (primary embryonic cartilage, which possesses abundant matrix and wide intercellular stretches) is cleanly excavated from within the tube of periosteal bone, and no direct transformation takes place. Miss Fell is driven, however, to believe that in endosteal bone, a direct transformation does occur. This is, of course, from the histological point of view a matter of great importance. But whether it be true or not, Miss Fell's work seems likely to throw light on the morphological question as to the nature of the so-called secondary cartilage, commonly found in developing mammalian membrane bones. So long as this secondary cartilage was regarded as equivalent to primary embryonic cartilage, there were constant difficulties in the way of homologising various bones which were purely membrane-bones in some forms, but appeared to have cartilaginous precursors in others. But it would seem that secondary cartilage is of the same nature as that hypertrophied cartilage which Miss Fell has obtained from endosteal tissue-culture; and if this is so, then a nodule of secondary cartilage and a mem-

brane-bone are from a morphological point of view equivalent, and an element which in one form develops as a pure membrane-bone, might in another start from a rudiment of secondary cartilage.

PALÆONTOLOGY.—The fishes from the Triassic of Greenland (Stensio, *Meddelelser om Grønland*, **83**, 3, 1932) have added largely to our knowledge of the Chondrostei and Cœlacanths. The Chondrostei are the commonest fossils and Stensio has attempted a new classification of the group incorporating recent work, as well as the new material from Greenland. He divides them into 6 groups A–F.

Group A.—The Palæoniscids in a broad sense representing the ancestral stock. New species of *Birgeria* and *Glaucolepis* being recorded from Greenland

Group B.—The deep bodied forms Platysomids, Bobasatranids and Dorypterids. The Platysomids leading backwards to the Palæoniscids, and the Bobasatranids and Dorypterids represent a line of evolution towards the Pycnodonts among the Holostei. A new and very perfectly known species of Bobasatrania is found in Greenland.

Group C.—The Pholidopleuridæ which represents an offshoot from the Palæoniscids towards the Pholidophorids. The new species of *Australosomus* adds greatly to our knowledge of this group.

Group D.—The Catopterids, Perleids, Ospiids, and Parasemionotids. The Catopterids and Perleids show most affinities with the Palæoniscids, the Ospiids and Parasemionotids with the Semionotids.

A new species of *Perleidus* is recorded and the family Ospiidæ erected for the two genera *Ospia* and *Broughia*.

Group E.—The Phanerorhynchidæ and Saurichthyidæ show very close relation with, and lead naturally on to *Group F* the Chondrosteids, Polyodonts and Acipenserids.

It is therefore evident that a most important advance has been made in the knowledge of the relationship of the Chondrostei to the Holostei. Firstly, it is clear that no sharp boundary can be drawn between them, and secondly the several different groups of the Chondrostei have independently evolved towards the Holostei which are in all probability a polyphyletic group.

The endoskeleton of the new Cœlacanth *Laugia* is of a modified archipterygial type and thus fundamentally disagrees with previous descriptions and suggests, as does all recent work, that the Cœlacanths are descended from a common ancestor with the Dipnoans and Osteolepids. The endocranium of the Dipnoi under-

went a progressive reduction of ossification between the Devonian and Cretaceous, and this is further supported by investigations by the grinding method on the Devonian *Diplocercides*, and *Laugia* appears to be somewhat intermediate between it and later forms.

The discovery of Amphibians from the Devonian rocks of East Greenland is particularly interesting, as it is the earliest fossil record of Tetrapods. Among the seven specimens described by Säve-Söderbergh (*Med om Grønland*, **94**, 7, 1932) are two genera *Ichthyostega* and *Ichthyostegopsis* forming the family Ichthyostegidæ As might be expected, these new forms go a long way to bridge over the gap between the Carboniferous Stegocephalians and the primitive Crossopterygians. They differ most markedly from the carboniferous Amphibia in the position of the nostrils on the ventral surface of the snout, the presence of an unpaired bone directly behind the parietals (parieto-extra scapula), an unpaired rostro-interrostral, a preopercular, and an undoubtedly enclosed lateral-line system on the head. All these characters are typical of the early Crossopterygians, except the ventral positions of the nostrils which have, however, been described by Stensiö in an unidentifiable Crossopterygian from Spitzbergen. The Ichthyostegids resemble the Embolomeri almost exactly in their palate, by the absence of cranial flexure, and by the possession of bones probably homologous with the septomaxillaries

The general shape of the skull resembles the Embolomeri and differs from the Crossopterygii in the relatively elongated anterior part, and shortened posterior part The Ichthyostegids appear, however, to be more specialised than the Embolomeri in some respects and have probably evolved independently from them.

Säve-Söderbergh (*Nov. Act. Reg. Soc. Sci. Upsal.*, Ser. IV, **9**, No. 2, 1933) gives a very detailed account of dermal bones of the head and lateral-line system of *Osteolepis macrolepidotus*. Although he adds here little that is new, he finds that the skull can be compared with the Cœlacanths, Dipnoans, and Tetrapods more readily than with the Actinopterygii. The preopercular is firmly built on to the cheek as in *Holoptychius* and *Eusthenopteron* and not loosely attached to the posterior margin as was previously thought, and the frequent subdivision of the parietals into anterior and posterior portions closely resembles the condition in other Crossopterygians. A very Tetrapod-like character is shown in the sclerotic plates which are numerous. He concludes that the Osteolepids, Cœlacanths and Tetrapods should be classified together as the " Choanata " with internal nares to emphasise the gap existing between them and the Actinopterygians.

Genetics.—Mather, K., and Stone, L. H. A., (1933, *J. Gen.*, **28**, 1–24) have done important work on the cytological basis of genetics. They have shown, once again, that the "attachment constriction" plays a fundamental part in the mechanics of cell-division. They find indeed that separate chromosome fragments, however long or short, invariably get lost unless they include it: should they do so, however, they are as invariably preserved. The most illuminating part of this paper, however, is the demonstration that during mitosis the division of the chromosomes into chromatids takes place during the resting-stage and not in the previous anaphase. The authors find that abundant chromosome abnormalities arise in cells irradiated during the resting-stage, but that none result from treatment during mitosis. Now if the abnormalities develop before the chromosomes split, they should occur in both the resulting daughter chromosomes. This they found always to be true, there being no unequal irregularities such as should result if the split took place prior to the resting-stage. They have therefore corroborated Darlington's precocity theory by means of evidence entirely different from that on which it was established.

Fisher's theory of dominance modification by means of selection operating on the gene-complex has received important corroboration recently (Harland, S. C., 1933, *J Gen*, **28**, 315–25.) In this paper Dr. Harland answers the criticism that the case of "crinkled-dwarf" in Sea-Island cotton is to be explained by failures of the simple Mendelian mechanism due to polyploidy. For in his extensive study of the cotton species he finds no instances of such failure as could provide a basis for this view. Further studies of this mutation when crossed with different "Upland" forms leads him to two interesting conclusions: first, that Fisher's theory is entirely confirmed and, secondly, that the particular genes responsible for modifying "crinkled dwarf" in the direction of recessiveness have been of advantage to the species independently of this effect. His generalisation that recessiveness may usually be due to the action of modifiers spread by selection on their own account, is probably pushed too far; but it undoubtedly provides an important means by which recessiveness may be more widely and quickly assumed by a gene in many cases.

Landauer (1933, *J. Hered.*, **24**, 153–6) describes a single recessive gene, widely spread in poultry, the effect of which is to convert the incompletely dominant gene "frizzle" into a recessive. Thus he gives a clear demonstration, (*a*) that dominance modification can be arrived at by genic interaction and (*b*) that presence

and absence even in the sense of selecting different degrees of activity in a series of multiple allelomorphs, cannot be regarded as a universal explanation of this phenomenon.

CYTOLOGY.—Several new techniques have been introduced recently for the study of the microscopical structure of cells and the chemical nature of the substances which they contain Perhaps the most striking of these is the " freezing-drying method " described by Bensley and Gersh in a series of papers (*Anat Rec*, **57, 58,** 1933). Tissues are frozen in liquid air, dried at a temperature of — 20° C. and then rapidly embedded in paraffin in vacuo and sectioned and stained in the normal way. It is assumed that this method could not alter the distribution of substances within the cells, and since after it lumps of chromatin are revealed in the nuclei of various animal cells, it is concluded that such nuclei contain lumps of chromatin even though these are invisible in the living state. Mitochondria were preserved by the technique, and it was found that acetic acid of 0·15 per cent to 5 per cent did not dissolve them , neither were they removed by fat solvents (ether, alcohol, etc.) On the other hand Millon's reagent, if properly used, gave a uniformly positive stain of the mitochondria and they were removed by peptic digestion. Mitochondria, therefore, are not of fatty but of protein nature.

The Nissl granules of nerve cells were seen in their usual form after the freezing-drying method, proving that the Nissl substance in the living cell is in the form of granules and not, as is often maintained, uniformly distributed. The substance was partly dissolved by alkalis but not by acids, peptic juices or nucleases. From these results Bensley and Gersh could only draw negative conclusions as to its nature, but Szent-Györgi (*Arb. ung. biol. Forschginst*, **5**, 177, 1932) showed that after alcohol fixation and paraffin embedding the Nissl granules were dissolved by ptyalin, and therefore concluded that they consist of polysaccharides, which agrees with their disappearance from the nerve cells during fatigue

Another new technique has been introduced by Policard (*Bull. d'Hist. appl.*, **10,** 1933) and named histospectrography. By means of it he is able to detect the presence and position of metals in tissues, and he has applied it to the study of copper in the liver during normal and pathological conditions and has found that during " chrysotherapy " gold becomes localised in the liver, kidney and adrenal.

Horning and Scott (*J. of Morph.*, **54,** 1933) have used the micro-incineration method for a study of the structure of the parasitic ciliates of the frog. Opalina which is saprozoic, was found to con-

tain no diffuse inorganic substance in its endoplasm, but only certain large "vegetative granules," consisting mainly of calcium oxide. In Nyctotherus, on the other hand, which is holozoic, there is a fine network of salts, with special concentrations round the mouth and cytoplasmic vacuoles

The micro-dissection technique has been used by Vonwiller and Audova (*Protoplasma*, **19**, 1933) for a thorough study of the cells of the salivary glands of Chironomus. The cell membrane is strong and can be bent inwards by a needle. The cytoplasm is viscous and no Brownian movement is seen in it; it can be cut into lumps, which only round off very slowly. The nucleus maintains its shape when removed from the cell and there is a very definite nuclear membrane which becomes folded when the nucleus is shrunk with hypertonic solutions and can be isolated as a separate structure. The nuclear contents are much less viscous than the cytoplasm and flow out when the membrane is punctured; Brownian movement can be seen in the nucleus, and the nucleoli can be moved freely within it. There is a continuous chromatin thread which is a gel and can be stretched out between needles and returns almost to its original length when released The nucleolus also has a firm consistency and when it is cut in half the parts retain their shapes.

Besides many chromosome studies, which are not dealt with here, there has been further elucidation of some of the problems of nuclear structure. Eichhorn (*Bull. d'Hist. appl.*, **10**, 1933) considers that in higher plants there are two types of nucleus, those which are optically homogeneous except for one or two nucleoli, and those which contain a chromatin network. He discusses the ways in which the chromosomes form in the two types of nucleus and considers that chromosomes are always optically homogeneous structures, the chromomeres, etc., being artefacts. In another paper (*C. r. Soc. Biol.*, **112**, 1933) he shows that in the resting nucleus of root meristem of Cucurbitacea, which is of the homogeneous type, one or two pro-chromosomes can nevertheless be distinguished near the nucleolus.

Hollande (*Arch. de Zool*, **75**, 1933) has continued his study of the cytology of the Cyanophycæ, concluding that these algæ have a definite nucleus consisting of two parts (epi- and centro-nucleosome) and that the scattered granules hitherto described as constituting dispersed and naked chromatin are not in fact nuclear material but a secretion of the cytoplasm.

Fry (*Biol. Bull.*, **63**, 1932) has made a careful study of the mitotic figure of the cleavage of Chætopterus, his main conclusion

being that the centriole is an artefact of staining. Progressive de-staining showed reduction of the apparent size of the centriole until it disappeared altogether at the same time as the spindle fibres became invisible. He therefore concludes that the apparent granule is nothing more than a collection of stain where the fibres converge. He has reached similar conclusions in a study conducted with Robertson (*Anat. Rec.*, **57**, 1933) of mitoses in the ependymal cells of Squalus.

The controversy as to the nature of the Golgi substance and its relation to neutral red vacuoles has continued. Several workers have reported that the bodies which stain with neutral red are formed de novo under its action. Thus Gatenby (*Am J. Anat.*, **51**, 1932) re-studied the cells of the salivary glands of Chironomus on which Parat and Painlevé based much of their argument, and came to the conclusion that the neutral red bodies are new formations and are not identical with the Golgi element which consists of rods with an outer chromophil and inner chromophobe part Similarly Nahm (*J. of Morph.*, **53**, 1933), who studied various types of gland cells in a variety of vertebrates, came to the conclusion that the neutral red vacuoles are neoformations She stresses the lack of specificity of osmium staining and finding that by lengthening the time of impregnation more and more Golgi substance appears, concludes that it is a fatty substance which gradually separates out from the cytoplasm. Banerji (*Bull. Acad. Sci. Allahabad*, **1**, 1932) showed that the Golgi element and neutral red vacuoles are distinct in the eggs of Scylla and that neither of these are of mitochondrial nature.

On the other hand several authors suggest that both preformed granules and neoformations are revealed by neutral red. Thus Schlottke (*Z. mikr-anat. Forsch.*, **32**, 1933) found that in the cells of the cœlenterate Coryne dyes such as neutral red, methylene blue and nile blue may either be taken up by existing vacuoles or secreted as new vacuoles which increase in size and run together. Volkonsky (*Bull. Biol. France et Belge*, **67**, 1933) studied blood cells of Sipunculus and found a typical vacuome and chondriome as described by Parat, though he admits that neutral red may also accumulate in vacuoles which are independent of the vacuome! Orska (*C. r. Soc. Biol.*, **113**, 1933) also came to the conclusion that neutral red may stain more than one type of structure. During spermatogenesis of the Lamellicorn beetle Cetonia there was found to be a single round Golgi body, which then gradually broke up into parts, some of which gave rise to the acroblast and acrosome. Neutral red stained these bodies at some, but not all stages and

in addition there appeared in the later stages of spermatogenesis certain other neutral red granules. There are therefore two sorts of vacuome, one "isotopic" and the other "heterotopic" with the Golgi apparatus. Weier (*Am. J. Bot.*, **20,** 1933) found granules which take up neutral red in the protonema of Polytrichum. When the solution used was dilute (1/30,000) the granules were stained but unaltered and the stain later gradually disappeared, but with stronger solutions the granules swelled, fused and passed into the vacuole.

Parat still holds to his theory that there are only two fundamental types of cell inclusion, and with Villela (*C. r. Soc. Biol.*, **112,** 1933) he has studied the sperms of the guinea pig and confirmed his original conclusions. He considers that the interpretations given by Gatenby and Hirschler are due to the examination of the sperms under unsatisfactory conditions. To this Gatenby and Duthie (*C. r. Soc. Biol.*, **113,** 1933) reply that the structures they have described can be seen in the living unstained cells of Abraxas, Lepisma and Rhodnius. They also contradict Parat on other points, asserting that the mitochondria of cavy spermatocytes are not thread-like but granular and that the intra-archoplasmic neutral red granules, which Parat holds to be the Golgi substance, are simply a secretion product of the latter. Grassé and Tuzet (*C. r. Soc. Biol.*, **113,** 1933) have also criticised several parts of Parat's description of spermatogenesis. In the same volume Parat answers these criticisms and continues to maintain his interpretation.

There is thus as yet no agreement as to the nature of these cell constituents, but nevertheless several workers have described functional changes in them which throw further light on the part which they play in the life of the cell. Thus Krogh and Okkels (*Bull. d'Hist. appl.*, **10,** 1933) have shown that after injection of extracts of the anterior lobe of the pituitary there are marked changes in the thyroid, the colloid disappearing from the vesicles and the Golgi apparatus undergoing a cycle of enlargement. Beams and King (*Anat. Rec.*, **57,** 1932) showed that the Golgi apparatus in ameloblasts changes its position as enamel begins to be laid down, so as to come to lie near to the enamel-producing surface. In the case of the cells of the anterior pituitary several workers (Wolfe and Cleveland, *Anat. Rec.*, **55,** 1932: Atwell, *ibid.* Severinghaus, *ibid.*, **57,** 1933) have recorded differences between the Golgi elements of the different types of cell and cyclical changes in these, but no detailed relationship of secretion granules to either Golgi element or mitochondria has yet been discovered in these cells. Noël and Pallot (*Bull. d'Hist. appl.*, **10,** 1933) have repeated on rats the experiments

made by Noël on mice and have confirmed his conclusion that during digestion the mitochondria of the liver change their form and produce certain large granules. These interesting results had been denied by Muggia and Masuelli in Italy and by Smith in America.

One of the most striking facts about the Golgi element and mitochondria is that they occur in every type of animal and plant cell and this generalisation can be extended as a result of the work of Saksena (*C. r. Soc Biol.*, **111**, 1932) who studied the hyphæ of the fungus Pythium and found neutral red granules, mitochondria and fat granules. Weier (*Am. J. Bot.*, **19**, 1933) studied the plastids of the moss Anthoceros and came to the conclusion that they are structural differentiations of the cytoplasm showing similar staining reactions to the Golgi apparatus of animals. They secrete starch granules in the same way as the Golgi apparatus produces secretory droplets. Further chemical information is, however, necessary before fully establishing the homology.

Finally, the vexed question of the homologies of the cell inclusions of Protista has been very thoroughly treated by Duboscq and Grassé (*Arch de Zool.*, **73**, 1933). The whole literature concerning the parabasal body is reviewed, many of the more important points being checked by personal observations. The parabasal apparatus is held to be lipoidal and to be double, consisting of chromophil and chromophobe parts. Its connection with the blepharoplast is compared with the connection of the idiosome with the centrosome of metazoan cells, and the authors conclude that there is sufficient evidence for homologising the parabasal with the Golgi apparatus. Its function is held to be to provide fuel and reserve material for the functioning of the flagella, and it may also have a secretory function (producing glycogen) and be a carrier of enzymes.

Hirschler, on the other hand, maintains that the parabasal body is mitochondrial (*Z. Zellforsch.*, **15**, 1932) and that the paracentrosome of Proteromonas is a "Progolgiom," which gives rise both to the Golgi apparatus and centrosome of higher forms. Hill (*J. Roy. Microsc. Soc.*, **53**, 1933) gives a critical review of the whole question of the cell inclusions of Protista and concludes that there is sufficient evidence to show that the Sporozoa possess a true Golgi element, but that it is not yet possible to decide whether either the parabasal apparatus or the contractile vacuole can be properly considered as such.

NOTES

The Analysis of Coal Ash (M. S.)

Although the standard methods for the determination of oxides of aluminium, calcium, magnesium, and iron, are suitable for the analysis of ashes from various coals, provided certain precautions are observed, yet more efficient methods are constantly being sought. In a recent publication of the Fuel Research Board (*Physical and Chemical Survey of the National Coal Resources*, No 28, H.M. Stationery Office) it is pointed out by Dr. Sinnatt that whereas this subject was formerly of scientific or academic interest, the proportions of the several constituents have become of practical importance owing to the probable catalytic action of these inorganic materials in the new processes for treating coal. It is with the hope that interest will be sufficiently stimulated to enlarge this branch of industrial analysis that the Fuel Research Board has placed on record the methods used at the Research Station.

In surveying the list of constituents a table of comparison with the proportions present in American coals serves to illustrate the general resemblances in the ashes from coals mined in the two countries; it is thus evident that methods of analysis published in either of the countries are mutually applicable. American coals yield ashes containing from 40 to 60 per cent. silica, whereas the corresponding value for British coals is from 25 to 50 per cent.; but apart from this there is little difference. A further table compares the proportions of constituents in ashes derived from coals from Lancashire, Yorkshire, South Wales, and two American states. Points of special interest in this list are: the presence of double the proportion of titanium oxide in the Welsh and Yorkshire coal ashes compared with the amount in ashes from the Lancashire seams; the high sulphate content of ashes from the Arley seam, Lancashire, the value being 10·77 per cent., while Yorkshire Parkgate coals yield 1·26 per cent. and American coals are yet smaller with 0·5 per cent. as a maximum; and the presence of twice the proportion of ferric oxide in the Lancashire ashes compared with other English coals. Much interest and value is attached to the

application of spectrum analysis for the rapid determination of certain constituents. In 1927, H. Ramage applied this method for the investigation of the flue dust from the combustion of South Yorkshire coal, and although his results are qualitative yet a wide number of rarer constituents such as gallium, lithium, and thallium, were identified. Dr Twyman has also applied this method in the case of Beamshaw coal from West Yorks, and has reported the presence of heavy traces of molybdenum, vanadium, and boron.

The report gives laboratory directions for the determination of silica by fusion with sodium carbonate, followed by precipitation with HCl, and volatilisation of the silica with hydrofluoric acid Iron, aluminium, and titanium are precipitated with ammonia and weighed together as the ignited oxides ; while from a further portion of the solution iron is precipitated as ferrous sulphide in order to separate it from any titanium. Manganese is determined by a modified sodium bismuthate method, magnesium is weighed as pyrophosphate, and calcium as sulphate or oxide. Other methods, often modified to form " Fuel Research " methods, are outlined for estimating phosphorus and other constituents of importance.

" Holocellulose " [Skelettsubstanzen] (A. G. N.)

In practically all scientific subjects progress, though continuous, is not at an even rate. There are foggy periods when direction is somewhat lost, and clearer times when the surroundings and the route ahead are more easily seen. Or to use another analogy, an apparently disorganised mass of observations from time to time accumulates, and then rather suddenly crystallises out to give gleaming clear-cut conclusions. At present it would rather seem that one of these crystallising periods is approaching in the field of work connected with the chemistry of the plant cell-wall. Wood chemists and plant chemists have for a long time been groping fitfully for an understanding of the structure of the cell-wall of mature cells. Ordinary analytical methods are not enough even to differentiate clearly between the various constituents, and certainly can be expected to give no information at all as to their arrangement. It is being realised more and more that to seek knowledge as to the structural association of cell-wall constituents by most of the current analytical methods is rather like attempting the dissection of a rabbit with a blunt axe. For the dissection of the cell-wall a finer tool is needed. This is being provided by physicists, using the methods of X-ray analysis. As a result, the concept of the aggregation of cellulose molecules into crystallites and micellæ, organised and oriented, has been developed. By this means, much light has

been thrown on the structure of fibres used in textile industries, and some attempt made to explain the basis for observed physical and mechanical properties. It is much to be hoped, however, that the same methods of attack may be applied in cellulosic materials of other than industrial significance, in short to the problem of the structure of the ordinary plant cell-wall, as opposed to isolated fibres. A start has been made in this direction and the admirable work by Astbury on the curious unicellular alga *Vallonia*, which was described in the last issue of this journal, serves to indicate the possibilities He has shown that the cell-wall of this organism is composed of a cellulosic fabric consisting of two crossed sets of cellulosic chains, and further that the direction of these chains corresponds to that of the striations visible on the surface, and which therefore must represent the "grain" of the ultimate framework. The examination of the isolated framework of plant materials should not be impossible and might yield conclusions of far-reaching significance. Too often has the chemist concerned himself only with the maltreated and distorted cellulose of industry, too frequently with that isolated in as mild a manner as possible from plant tissues. It is to be hoped that the physicists will not similarly lead themselves astray.

As the physicist reveals the cellulosic architecture of the tissues so must the chemist describe the constituents involved. Gone are the days when the existence of lignocelluloses, pectocelluloses, etc., were preached and accepted, at any rate in so far as direct combination between lignin or pectin and cellulose is concerned. In place of these views there is, however, nothing which can be definitely put forward. The concepts of the state of high molecular aggregation of polysaccharides and the orientation of cellulose molecules into crystallites and micellæ, have entirely changed the outlook. Secondary valency forces may be more important than primary valency linkages in the association of cell-wall constituents. For this reason any method which makes possible the removal of any one particular constituent from the cell-wall is of great value. Schmidt [1] described a method by which the lignin could be removed from wood, leaving a carbo-hydrate residue comprising the cellulose, associated cellulosans, and encrusting hemicelluloses or polyuronides. Any other method of removal at the same time causes the polyuronides to be lost. The residue obtained by him comprises virtually all the polysaccharides of the wood, and was termed "Skelettsubstanzen." His method, which employed chlorine dioxide in pyridine, has

[1] Schmidt, E., Tang, Y. C., and Jandebeur, W., *Cellulosechemie*, **12**, 201 (1931).

the great disadvantage that a month or more is necessary for satisfactory removal. Very recently Ritter and Kurth[1] have so improved it, that the whole procedure may be carried out in about ten hours. They employ alternate treatment with chlorine gas and extraction with alcohol-pyridine. The last traces of lignin are removed by standing in calcium hypochlorite. The residue obtained by them corresponds almost exactly to the "Skelettsubstanzen" of Schmidt, and they term it "Holocellulose," a choice of word that seems no happier than that which it is designed to replace.

However, apart from the slippery paths of nomenclature this marks a definite advance, inasmuch as it is now possible to study for the first time the association of the hemicelluloses with the cellulose. Hawley and Norman[2] suggested that the hemicelluloses are divisible roughly into two major groups, the polyuronides containing uronic acids and the cellulosans from which uronic acids are absent, the former being the encrusting substances and the latter being distributed among and so intimately associated with the true cellulose as to be isolated with it in the Cross and Bevan cellulose product. It is possible that the division drawn by them was too sharp, and that there are small quantities of uronic acids in the materials associated with the cellulose. This new method will enable this important point to be cleared up. Further it has already been the means of demonstrating that all of the acetyl and methoxyl groups in wood are not attached to the lignin. While it seems that the major part of the methoxyl is so, practically all the acetyl groups are associated with the "holocellulose" fraction. It will therefore be possible to study the distribution of these groups and perhaps to isolate polyuronide components to which methoxyls and acetyls are attached. Further, the solubilities and rate of removal of the polyuronides by various treatments may be investigated and compared with the solubilities of the reprecipitated material. By this means some information as to the form of association of this group with the cellulose might be obtained. There are other possibilities too, but sufficient has been said to indicate the value of the method. It is still a little tedious and ten hours or more are required for the delignification of such a well-behaved substance as maple wood (straws and non-timber materials would probably require much longer), but it seems not unlikely that the method might be improved, possibly by the substitution of some form of liquid chlorination for the gaseous treatment.

[1] Ritter, Geo. J., and Kurth, E. F., *Ind. and Eng. Chem.*, **25**, 1250 (1933).

[2] Hawley, L. F., and Norman, A. G., *Ind. and Eng. Chem.*, **24**, 1190 (1932).

The Electrostatic Loudspeaker (S. K. L.)

The principle of the electrostatic loudspeaker is simple. The device is essentially a condenser of extended area, across the electrodes of which are applied electric oscillations. The resultant forces between the electrodes gives rise to mechanical displacement and therefore to corresponding sounds. Various attempts to produce a satisfactory article have been made for some years but without much success. Recent developments are more promising, however, and a description of them is given by M G. Scroggie in the *Wireless World* for September 15, 22, and 29.

An air dielectric is generally used in electrostatic speakers to allow reasonably free movement of the electrode diaphragm. In order to overcome the cushioning effect of the air, the electrodes must be very thick or tightly stretched to obtain rigidity if they are thin. The stretched diaphragm type has been intensively studied by Hans Vogt in Germany. In America, the Kyle speaker has a diaphragm stretched over a slotted and ribbed metal plate, so that it behaves as a number of miniature diaphragms.

The "Primustatic" speaker, developed in this country and recently placed on the market, is regarded as a speaker in which a still closer approach to unrestricted motion is obtained. In this type, one electrode is a perforated aluminium plate slightly curved, and behind it is a tinfoil-coated sheet of waxed paper pleated so that the enclosed dielectric spaces have the shape of triangular prisms. The paper touches the fixed plate in straight lines between the perforations, and is held there by a special thread which makes light but adequate contact everywhere. When a potential difference is applied to these two electrodes, a sort of rolling action occurs in the paper, and the air is expelled through the perforations.

Since the mechanical force of attraction is independent of the sign of the applied potential difference, an electrostatic speaker requires a priming, or polarising, potential in order to avoid the frequency-doubling effect. Early types required polarising potentials of 1,000 volts or so, but in the Primustatic speaker 250 volts is sufficient. Since the amplitude of the motion is unavoidably limited, it is difficult to reproduce low frequencies at high intensity. On the other hand, the extremely light diaphragm actuated uniformly over its entire surface gives excellent reproduction at the higher frequencies. Focusing and interference effects obtained with a cone type speaker are not encountered here. At present, it is considered best to use a combination of an electrostatic speaker and an orthodox moving-coil speaker to obtain satisfactory overall repro-

duction, relying on the moving-coil speaker to cover only the lower frequencies.

The second and third parts of the article are concerned with the application of the electrostatic speaker as a load in the output circuit of a valve amplifier. The cases of a triode and a pentode are strikingly different, on account of the fact that the load is capacitative. The capacity of the Primustatic type averages about 0·008 microfarad per square foot, the value of course depending on the applied voltage Circuit diagrams showing the use of an electrostatic speaker with a triode and a pentode output valve are given, and also for dual systems in which a moving-coil speaker is used to cover the lower frequencies which cannot be handled by the electrostatic speaker.

Report on the Water Supplies of the F.M.S. (C. B. F.)

The effective utilisation of the natural wealth of intertropical lands is dependent on success in overcoming the special dangers to health associated with their climatic conditions. This report [1] on water supplies in Malaya is of considerable interest in that it describes some methods of dealing with the problem of obtaining safe water in such a region. The Malay Peninsula is an equatorial area of abundant rainfall, ranging from 80 inches to over 240 inches in the year. The shade temperatures recorded have never reached 100° F., but the mean maximum is more than 90° and the mean minimum 72°, in the lowlands. On the mountains the nights are sometimes cool; and minimum temperatures as low as 40° have been recorded at hill stations. The climate is one of constant heat and high humidity (over 80 per cent.). There is no cool season and no dry season. Under these conditions water is abundant, and there are no difficulties in securing adequate quantities for the towns and plantations. Nearly all the catchment areas are in either virgin jungle or forest reserves; and there is little risk of pollution from the drainage of cultivated land. But the jungle streams contain a high proportion of organic matter; and water-borne diseases are widely prevalent. Hence the purification of the waters is of great importance. The treatment usually includes, besides filtration, the addition of lime and alum, and chlorination. Most of this volume is occupied by tables stating the results of chemical and bacteriological analyses of the waters before and after treatment. These tables, and the brief notes which accompany them, contain informa-

[1] *The Water Supplies of the Federated Malay States*, by R. W. Blair, *Bulletin No. 2*, of 1933, from the Institute for Medical Research, Kuala Lumpur, F.M.S., 1933.

tion of value to anyone concerned with the problem of safe water supply in a hot climate. They also demonstrate the value of the scientific services in the fight against disease in such regions.

Journal of Population (E. J. S.)

The articles in the first number of the new journal *Population* which has recently appeared are chiefly concerned with the changes which the world's population has undergone in recent years. The decline in birth rate though partially compensated by a decreased infant mortality has reached the point, in Britain and in Belgium alike, where a stationary or diminished population can be prophesied in the near future. This decline is apparently characteristic of a particular phase of development of society and is independent of climatic conditions or geographical position, being shared in greater or less degree by most white peoples. Sir Charles Close in an interesting review of the population situation in south and east Asia emphasises the negligible contribution which emigration makes to the solution of the problem and aptly summarises the position by a question. "Should a philosopher-statesman prefer an India of 350 millions, of short-lived, underfed, uncultured people, or an India of half that number, but fitter in mind and body; with greater opportunities for self-development and expression?" In the words of the Shorter Catechism, "What is the chief end of Man?" For which the ribald reply "the end with the head on" will have a new significance after the perusal of these pages. No one can doubt the importance of the population changes that are taking place both in respect to their biological implications and practical effects, nor is it necessary to stress their fundamental relation to statesmanship. A journal devoted entirely to their study is therefore a welcome and timely addition to the ever-increasing number of specialist periodicals (*Population*, Journal of the International Union for the Scientific Investigation of Population Problems. Allen & Unwin).

Miscellanea.

The New Year Honours List included the following awards: *K.C.V.O.:* Sir Richard Glazebrook, until lately Vice-Chairman of the Executive Committee of the National Physical Laboratory. *Knights:* Dr. S. C. Cockerell, director of the Fitzwilliam Museum, Cambridge; Mr. G. Evans, principal of the Imperial College of Tropical Agriculture, Trinidad; Dr. Kenneth Lee, chairman of the Industrial Grants Committee, Department of Scientific and Industrial Research; Prof. Robert Muir, professor of pathology,

University of Glasgow. *C B.E :* Mr. J. S. Buchanan, deputy director of technical development, Air Ministry; Mr. R. G. Hatton, director of the Horticultural Research Station, East Malling, Kent. *O.B E :* Mr. G. H. J. Adlam, senior science master, City of London School; Mr. C. Coles, principal of Cardiff Technical College; Dr. W. Makower, professor of science, Royal Military Academy.

The Catherine Wolfe Bruce Gold Medal of the Astronomical Society of the Pacific for 1934 has been awarded to Prof. A. Fowler, F.R S., for his distinguished work in astronomy.

The Gold Medal of the Royal Astronomical Society has been awarded to Dr Harlow Shapley for his work on the galactic system.

The Symons Gold Medal, awarded biennially by the Royal Meteorological Society for distinguished work in meteorology, has been awarded to Prof. Sir Gilbert Walker.

The University of Lille has awarded a medal to Mr. W. T. Astbury in recognition of his valuable work on the X-ray analysis of the structure of fibres with special reference to his address on that subject delivered to the Thirteenth Congress of Industrial Chemistry at Lille last September.

The meeting of the British Association this year will be held in Aberdeen during the period September 5-12. The presidents of the various sections will be: Section A (Mathematics and Physics), Prof. H. M. Macdonald; B (Chemistry), Prof. T. M. Lowry; C (Geology), Prof. W. T. Gordon; D (Zoology), Dr. E. S. Russell; E (Geography), Prof. A. G Ogilvie; F (Economics and Statistics), Prof. H. M. Hallsworth; G (Engineering), Prof. F. G. Bailey; H (Anthropology), Capt. T. A. Joyce; I (Physiology), Prof. H. E. Roaf; J (Psychology), Dr. Shepherd Dawson; K (Botany), Prof. A. W. Borthwick; L (Education), Mr. H. T. Tizard; M (Agriculture), Prof. J. A. S. Watson. Sir William B. Hardy, F.R.S., director of Food Investigation in the Department of Industrial and Scientific Research was to have been president of the Association for the current year but unhappily his name is among those in the obituary list this quarter and Sir James Jeans has been elected in his place.

The Sixth International Botanical Congress will meet at Amsterdam on September 2–7, 1935. The secretary for the meeting is Dr. J. M. Sirks, Wageningen, Holland.

Prof. G. N. Watson has been elected president of the London Mathematical Society for the current session, Prof. W. A. F. Balfour Browne, president of the Royal Microscopical Society, Col. E. Gold, president of the Royal Meteorological Society, and Sir Thomas Holland, president of the Mineralogical Society.

We regret to have to record the announcements of the death of the following well-known scientific men during the past quarter: Mr. H. F Biggs, mathematical physicist; Dr. F. L. Chase of Yale University, astronomer; Prof. J Cossor Ewart, F.R.S., zoologist; Prof. W. E. Gibbs, chemical engineer; Dr. F. H. H. Guillemard, geographer; Prof. F. Haber, physical chemist; Sir William Hardy, F.R.S., president-elect of the British Association; Prof. J. Joly, F.R.S., of Trinity College, Dublin; Dr. F. L. Kitchin, F.R.S., palæontologist; Sir William Lawrence, lately treasurer of the Royal Horticultural Society; Sir Donald MacAlister, K.C.B.; Mr. H. M. Martin, of *Engineering*; Sir Frederic Nathan, power engineer; Dr. Knud Rasmussen, explorer; Dr. D. H. Scott, F.R.S., botanist; Prof. T. Swale Vincent, physiologist; Dr. H. S. Washington, geologist; Mr. A. E. P. Weigall, archæologist.

Opening a discussion on the heavy isotope of hydrogen at the Royal Society on December 14, Lord Rutherford pointed out that the name *deuton* suggested by Prof. Lewis for the H^2 nucleus, is easily confused in speech with neutron and therefore not very convenient. Deuton follows from *deuterium*, the name suggested by Urey, one of its discoverers, for the isotope itself, and Rutherford proposed instead *diplogen* for the isotope and *diplon* for its nucleus. In *Nature* (Feb. 3) Urey, Brickwedde and Murphy state that before suggesting *deuterium* as a suitable name for the isotope they considered many others, including *diplogen*, and rejected them on various reasonable grounds. H. E. Armstrong also objects to diplogen which he considers " philologically unsound and bereft of

The eighth Conférence Générale des Poids et Mesures met in Paris on October 3 and was attended by delegates representing 29 out of the 31 nations adhering to the Convention. The most interesting decision was taken on the recommendation of the Advisory Committee on Electricity. It was agreed that in future the electrical standards should be based on the absolute C.G.S. units and not on the present International system which involves the mercury ohm and the silver voltameter. The change in the

units is intended to be made on January 1, 1937, by which time the International Committee will state the magnitude of the alteration required. From a paper read by G. A. Campbell of the American Telegraph and Telephone Co. before the International Union of Pure and Applied Physics in Chicago last June, it would appear that the International Ohm is 460 parts in a million greater than the Absolute Ohm, so that the change will involve an increase of about 1 part in 2,000 in the marked values of all resistance coils. This is five times the tolerance allowable in precision commercial apparatus but for the other units the change involved is much less than the accepted tolerance. The International Volt is 360 parts in a million greater than the absolute volt and the International Ampere 100 parts in a million smaller. In each case the accepted tolerance is 1 in a 1000.

Campbell's paper is printed with others on the same subject in *Bulletin No. 34* of the National Research Council of the United States (National Academy of Sciences, Washington, D.C., $1.00). They show the extraordinary confusion which has arisen from the introduction of various "improvements" on the system used by most writers in this country and the urgent need for international agreement The chief points at issue seem to be the use of the C.G.S. or M.K.S. systems and the question of rationalisation (*e.g.* whether the magnetomotive force round a circuit shall be taken as ni or $4\pi ni$). Recent decisions regarding the names of units have not been helpful and are likely to cause trouble for some years. The *gauss*, for example, has become well established as the C.G.S. unit of magnetic field strength (H); there seems little reason, certainly no historical reason, for changing the name to *œrsted* and transferring *gauss* to the unit of flux density (B). Suggestions for fancy names abound but, whatever the ultimate decisions of the International Congress may be, it is unlikely that such monstrosities as *kog* (kilogram), *abdaraf* (reciprocal of the absolute e.m. unit of capacity) and *pragilbert* (whatever that may be) will appear very frequently in standard English textbooks.

The *Report of the Advisory Council of the Committee of the Privy Council for Scientific and Industrial Research* for 1932-33 summarises very briefly the results which have followed from the disbursement of the million pound fund placed at its disposal sixteen years ago. It appears that this grant has attracted a total contribution of about one and three quarter million pounds from industry and that the present annual expenditure on nineteen research associations is £235,000 of which £65,000 is provided by the State.

Inasmuch as the net annual output of the industries concerned is worth no less than £440,000,000 their support is neither generous nor even adequate. The *Report* mentions a few of the financial returns that industry has received from its investment and it is evident that such benefits need to be underlined as they have been in the United States. An appendix to the *Report* contains a list of the existing Research Associations, together with the grants they have received from the Council but gives no information as to the contributions made by the several industries themselves. Four Associations, however, are self-supporting, namely, those maintained by the Scottish Shale Oil Industry, the Cutlers, the Colliery Owners and the Printers.

The main body of the *Report* details very briefly the work of the laboratories and associations controlled by the Council, the former now including the National Physical Laboratory, the Geological Survey and Museum, and the Building, Chemical, Food, Forest Products, Fuel and Road Research Laboratories. Among many interesting results one obtained by the Wool Industries Research Association may be mentioned. A process has been devised for treating woollen fibres in bulk before they are spun so as to render them individually unshrinkable. "Shrinking" as now practised is carried out on the woven fabric and the process used may weaken the fibre substance. The Launderers' Association has devoted much attention to methods likely to minimise damage to fabrics and has introduced new detergents in place of soap and soda, in particular sulphonated fatty alcohols. The Boot and Shoe Association is concerned with the reduction of the time, *e.g.* for drying, which must be allowed to elapse between the various processes of boot manufacture. It appears that with modern machinery a pair of boots is made in 30 minutes but that these minutes may be spread over a period as long as 3 weeks. The Food Investigation Board is still concerned with problems of production, of storage and of large-scale transport. The equally important matters which arise when food leaves the wholesale store have so far received only indirect attention.

Miscellaneous Publication, No. 143, of the Bureau of Standards contains psychrometric charts designed by D. B. Brooks to give the pressure of the water vapour in the atmosphere and the relative humidity when the readings of the wet and dry bulb thermometers and the barometric pressure are known. Two nomograms are supplied, one for use with the Fahrenheit scale and the other with the centigrade scale. The latter is based on the latest determinations of the constants in Ferrel's formula namely, $p = p' - 0{\cdot}000652B(t - t')$

$(1 + 0{\cdot}00102t')$ where $t°$ C and $t'°$ C are the readings of the dry and wet bulb thermometers, and B, p and p' the barometric pressure, the actual pressure of the water vapour in the atmosphere and the saturation pressure at the temperature of the wet bulb respectively, all three pressures being expressed in millimetres of mercury. The wet bulb scale is extended below 0° C. for use when the water on the wick is super-cooled or frozen; the author states, however, that below 0° C. it is better to use an ice-coated bulb and for this an auxiliary scale is provided. The effect of air velocity is not mentioned.

To illustrate the use of the charts the author takes the values $t = 35°$ C., $t' = 21°$ C., $B = 770$ mm. and finds $p = 11{\cdot}5$ mm. and the relative humidity $h_r = 27{\cdot}20$ per cent. For these data Glaisher's tables give $p = 10{\cdot}94$ mm, $h_r = 26{\cdot}0$ per cent while Apjohn's formula, with Rizzo's constant for the Stevenson screen (Kaye and Laby), gives $p = 11{\cdot}45$ mm and $h_r = 27{\cdot}25$ per cent.—an agreement well within the experimental error The charts are much easier to use than tables and it is therefore worth noting that they can be obtained from the Superintendent of Documents, Washington, D.C., price 5 cents. Strangely enough in the specimen sent to us the instructions are printed upside down on the back of the folder and the punctuation on the two nomograms is different. Such oddities, however, are of no importance to the user.

The *Report of the Water Pollution Research Board* for the year ending June 31, 1933 (H.M. Stationery Office, 1*s.* net), states that investigations of methods of reducing the volume of various domestic and trade effluents or of improving their composition are still in progress. By modifications of factory procedure in beet-sugar manufacture the major quantity of the waste water can be used again; by suitable design the discharge of polluting effluents from coke-oven installations can be reduced so as to be inappreciable, and a method has been devised for the purification of dairy waste. The possibility of softening water on a large scale by filtration through sodium aluminium silicates is being explored and the conditions under which water may be contaminated by lead, *e.g.* from lead piping, are being examined. Not the least interesting part of the *Report* deals with the paratyphoid epidemic at Epping in 1931. The outbreak was due to infected milk, but part of the Epping sewage discharges into Cobbins Brook and thence enters the Lea above the Metropolitan Water Board intake. Elaborate precautions were taken to ensure the purity of the water drawn from this river and, for a short while, it was not used at all. Even at

the end of June 1933 the effluent from the Epping sewage plant still contained paratyphoid bacilli.

The study of the effect of wind pressure on buildings and other structures is one which is receiving considerable attention in various parts of the world, and it is becoming increasingly evident that the rules laid down for this factor in all building codes, which specify only for an increase of pressure in the wind direction, are unsatisfactory.

At the request of the Building Research Board, experiments are being carried out by the National Physical Laboratory, Teddington, with the object of obtaining data which will enable the subject to be placed on a scientific basis. One stage of this research has been completed, and the results are embodied in a report just published by the Institution of Civil Engineers (*Selected Engineering Paper No. 139*, *Wind Pressures on Buildings*, by A. Bailey, M.Sc., A.M.Inst.C E.). Experiments have been made both on an actual building and on a model structure in a wind tunnel. The full-scale experiments were carried out on a large shed situated at Manchester, and tests were made in a wind tunnel at the National Physical Laboratory on a 1/240th scale model of the same shed. A large number of measurements of the wind pressure were made at different parts of the structure, and a careful comparison was made of the full-scale and the model results. One result of the experiments has been to show that the negative pressure (*i.e.* suction) produced on the leeward side of a building by a high wind is generally much greater than had been suspected. This result is of considerable importance from a practical point of view, since there is no doubt that in the majority of cases the damage to property caused by high winds is local damage due to the momentary reduction of pressure on the leeward surfaces, sometimes combined with an increase in the pressure inside the buildings due to openings on the windward side. These effects were very clearly demonstrated by the extensive damage to property which occurred at Birmingham during the gale in June 1931. Photographs of the damaged property are reproduced in the report, showing in one case a block of ten houses from which the roof was completely lifted, and in another a house with an entire wall pulled outwards. The paper also contains information on wind gradient and its effect on the pressure on buildings.

We have received from the Oxford University Press a copy of a recently published *German Reader for Biology Students* (5s.). The

text consists of passages from recent German scientific publications selected and arranged by Prof. Fiedler and Dr. J. R. de Beer, together with a vocabulary by Herma E. Fiedler. The subject-matter has been well chosen so that its study will teach the reader not only German but some interesting facts of biology. The print and general get-up of the book are excellent and add much to the attractiveness of a book which can be confidently recommended to those in search of assistance in acquiring a knowledge of scientific German.

Edward Arnold & Co. have published a pamphlet (1*s*. net) containing tables for the reduction of the readings of the platinum resistance thermometer to the International Temperature Scale. They have been computed by G. S. Callendar and F. E. Hoare and give (*a*) the values of $t - pt$ for values of pt between 0° C. and 1000° C., assuming δ to be 0·00015, (*b*) the corrections to these data for a change of 0·000001 in the value of δ. The values of $t - pt$ are given for each degree centigrade to the fourth decimal place between 0° C and 139° C., to the third place between 140° C. and 499° C., and thereafter to two places. The tabulated data are preceded by the necessary explanatory matter and the printing is admirably clear.

ESSAY REVIEW

THE CONVERSION OF CHARLES DARWIN. By Professor JAMES RITCHIE, Natural History Department, University of Aberdeen. Being a review of Charles Darwin's **Diary of the Voyage of H.M.S. "Beagle."** Edited from the MS by NORA BARLOW. [Pp. xxx + 451, with 3 illustrations and 2 maps.] (Cambridge: at the University Press, 1933. 21*s*. net.)

To have been written by a naturalist, a British naturalist, and the naturalist whose speculations were later to modify the thought of the world, Charles Darwin's *Diary of the Voyage of the "Beagle"* is a remarkable book. For British naturalists have a fine tradition of field observation, and this Diary is remarkable because of the insignificance of its field observations concerning animals and the lack of any indication of a consciousness awaking to a new interpretation of Nature. Yet, in Darwin's own estimation, the voyage of the *Beagle* was "by far the most important event in my life and has determined my whole career"; and his observant father even noticed on the return of his son, from a voyage which had lasted for the long period of five years and one hundred and thirty-six days, that "Why, the shape of his head is quite altered." But this development is not reflected in the *Diary*, and we are driven to ask what part the observations, recorded hot-haste in pencil in those eighteen little much-rubbed pocket-books from which the *Diary* was transcribed, played in the formulation of the great ideas of evolution and natural selection.

DARWIN'S NATURAL HISTORY TRAINING.—To what extent had Darwin's training fitted him to benefit from the voyage of the *Beagle*? After a boyhood which displayed probably neither more nor less of the nature curiosity and collecting habits common to many country boys, he was sent as a medical student to the University of Edinburgh in 1825. The lad of 16½ years of age rebelled against the Scottish lecture system: in his first year, "Dr. —— made his lectures on human anatomy as dull as he was himself"; in his second year "——'s lectures on Geology and Zoology . . . were incredibly dull." To be quite fair to his teacher, and quite frank with Darwin, this is not what others thought of Professor

Jameson, who then occupied the chair of natural history; for he is said to have been as remarkable as was his teacher, Werner, for his power of imparting his own enthusiasm to his students, and having myself been in charge of the natural history collections which he brought together and which ultimately formed the foundations of the collections in the Royal Scottish Museum, I know with what assiduity he gathered material and (more striking evidence) with what assiduity former pupils, scattered throughout the world, collected and forwarded specimens to him. Indeed Darwin, like many a student since—for the attack upon the lecture system still goes merrily on—wished to have systematised knowledge without the drudgery of learning.

Casual information he was quite prepared to pick up; it came easily and with interest; and so we find him hobnobbing in the Museum with Macgillivray the ornithologist, later a predecessor of my own in Aberdeen; with Grant and Coldstream, the former of whom took him to the rich shore pools of the Firth of Forth or to the meetings of the Plinian and Wernerian Societies; with the fishermen at Newhaven, with whom he dredged oysters in the Firth and got many specimens. Perhaps unconsciously another influence played upon him. The medical curriculum in Edinburgh came to be the narrow path which led many a naturalist explorer to distant fields and seas. James Bruce and Mungo Park had gathered knowledge and fame in Africa; none knew the Arctic Seas better than William Scoresby; in the very years of Darwin's own studentship, Sir John Richardson was surgeon and naturalist upon his second voyage with Franklin. Perhaps this Edinburgh tradition of exploration influenced Darwin more than he knew.

Two years at Edinburgh, and then an equally unsatisfactory three years at Cambridge, where he "did not even attend Sedgwick's eloquent and interesting lectures," he had been "so sickened with lectures at Edinburgh," and where his chief pursuit was the collecting of beetles. But he made many good friends, in his last year he came to realise that science meant more than the recording of casual facts, and he read and was inspired to emulation by Humboldt's *Personal Narrative*.

Such, in brief, was Darwin's scientific preparation, apparently not very extensive and not very intensive, for his naturalist voyage on the *Beagle*.

Darwin's Outlook at the Time of the "Voyage."—If there was little in Darwin's scientific preparation to suggest the great results which were to follow from his voyage, there was less in the mental outlook of himself and his shipmates to indicate the direction

of his future speculations. His own aim in life was to settle down in the peace of a parsonage where he could enjoy the country sports to which he was devoted. "Had he remained at home," says his editress, "with the opening of the partridge season as the all-important date to look forward to, would the almost fixed purpose of becoming a clergyman have been accomplished? . . . Science was hardly considered a career in those days, and even after five months' travel Charles still wrote in a letter home, 'I find I can steadily have a distant prospect of a very quiet parsonage, and I can see it even through a grove of Palms'" (p. x).

A second influence, more inimical to the development of new ideas, was that of the Captain of the *Beagle*, Robert FitzRoy, a great surveyor, who was "a devout believer in the first chapter of Genesis" and whose almost fanatical outlook developed during the voyage in the fervour with which he held creationist views. A happy friendship existed between the two, but the ascendancy of the older man over the youth of twenty-two must have had its influence in checking the free play of speculation. Nevertheless, although in the latter years of the voyage the overstatements of the creationist Captain must have tormented Darwin's sense of fairness, the Diary shows little sign that the speculations of the latter led him far from the almost generally accepted view of his time.

Indeed, casual comments, passed upon a variety of occasions, show how deeply set in Darwin's mind was the idea of creation in its simplest form. Speculating upon the primitive condition of the Fuegians he says, "Whence have these people come? Have they remained in the same state since the creation of the world?" (p. 213). During his country walks in the neighbourhood of Valparaiso he was much impressed by the scarcity of insects, as well as of birds and mammals, in a land where he found beds of recent shells at an altitude of 1,300 feet above sea-level; and he suggests that "it seems not a very improbable conjecture that the want of animals may be due to none having been created since this country was raised from the sea." Even in the Galapagos Islands, where he collected assiduously, and the fauna of which at a later date had so much influence in moulding his thoughts upon evolution, he could still write "it will be interesting to find from future comparison to what district or 'centre of creation' the organised beings of this archipelago must be attached" (p. 337).

The *Beagle* touched at some of the most interesting islands in the world, where all islands possess faunas of special significance; but, as it passed before his eyes and mind, the pageant, looked upon with pleasure and with wonder, seems to have roused no new thought

leading towards the speculations of later years In New Zealand he remarked upon the scarcity of birds, and was impressed by the fact that a country so large, so varied in altitude and climate, "should not possess one indigenous animal [mammal] with the exception of a small rat" (p. 372), but that was all In Australia he pondered upon "the strange character of the animals of this country as compared to the rest of the World," and made a suggestion in keeping with the ideas with which he set out. "An unbeliever in everything beyond his own reason," he wrote, "might exclaim 'Surely two Creators must have been at work; their object, however, has been the same and certainly the end in each case is complete'" Then his eye fell upon the conical pit-fall of a Lion-Ant, the European parallel rose to his mind, and he answers the disbeliever with the believer's answer: "Would any two workmen ever hit on so beautiful, so simple, and yet so artificial a contrivance? It cannot be thought so. The one hand has surely worked throughout the universe. A Geologist perhaps would suggest that the periods of Creation have been distinct and remote the one from the other; that the Creator rested in his labor" (p. 383).

That is a most significant statement, for it was made during the last year of the voyage, when almost the whole of the great survey had been completed, and it suggests, as the other quotations I have made suggest, that Darwin remained throughout the voyage steadfast in the non-evolutionary beliefs with which he embarked five years before. The *Diary* shows that the conversion of Charles Darwin did not take place during the voyage of the *Beagle*.

WHAT THE DIARY REVEALS.—Although the *Diary* reveals no trace of a mind awakening to a new interpretation of nature, it does show the increasing grip which the study of natural history was laying upon its author, and the veering of his interests from a geological to a biological bias. It shows the growing confidence of the field-naturalist, full of enthusiasm, in the value of his records, and in the possibility that they may contain a new message for the geologist and the naturalist. It shows an observer, dogged at sea by severe sickness and suffering from illness and hardship on land, taking no end of trouble to see what was to be seen, and recording his observations with care, often at great inconvenience.

And although the zoological observations are often slight and seldom betray the combination of intense interest in and sympathetic speculation concerning animal life which characterised the work of naturalists like Gilbert White, yet there are records of special interest. On October 31 (1832), out from Monte Video, "all the ropes were coated and fringed with Gossamer web. I caught some

of the Aeronaut spiders which must have come at least 60 miles"—and, curious fact, in another hemisphere, at the opposite season of the year Gilbert White recorded gossamer filling the air, October 15–17. Darwin noted the scarcity of life upon several of the Oceanic islands, and grew enthusiastic over the "infinite numbers of organic beings with which the sea of the tropics, so prodigal of life, teems" The lagoon at Keeling Island gave rise to the suggestion that the lagoon formation of coral reefs might be due to the sinking of the sea-floor

It may be said however, that, granted detailed zoological observation is scarce, one has no right to look for it in the *Diary*, for the records of Darwin's scientific observations were kept in separate note-books (p. ix), and the *Diary* was rather a record of impressions, picturing the doings of the young naturalist "in the first freshness and eager enjoyment of life." But we are attempting to gauge the growth of Darwin's great ideas, and must assume that any observation which he considered of vital interest would find a place in the *Diary*. When, moreover, we turn, in the final pages of his work, to his own stirring account of the influences which the voyage made upon him, and find his enthusiasm for natural scenery and the sublimity of primeval forest, for the beauty of the southern night, for the glacier, the waterspout, the active volcano, and the wonder of barbarian man, but not a word about any zoological influence other than the remarkable spectacle of a "lagoon island, raised by a coral-forming animalcule," then we are driven again to the conclusion that the five years' experience of the voyage had not yet evidently stirred the deeper wells of thought.

THE TRANSFORMATION OF VIEW.—Further discussion passes beyond the range of the *Diary*, for Darwin's conversion to the ideas of evolution and natural selection fell in later years, although the materials he amassed upon the voyage formed a factual basis with which he could not have dispensed.

The first edition of the *Journal of Researches during the Voyage of H.M.S. "Beagle"* was published in 1839, the text having been completed two years previously; it shows, as Francis Darwin has pointed out (*Life and Letters of Charles Darwin*, vol. II, 1887) practically no change of view from the *Diary* on which it was based. The second edition was published in 1845, and here, although the expressions "creative power" and "creation" are used in the old sense, there occur deletions and explanations which show that the evolution of the evolutionary idea was in progress.

What happened between the years of the appearance of the two Journals, so to influence the trend of Darwin's thought? He had

read Lyell's *Geology*, but he had both the volumes of that work ere the voyage itself was completed. He had read Malthus (in 1838) and that gave him a first clear view of the potency of natural selection. But to a thorough mind like Darwin's a theoretical conception, unbacked by facts, could have been of little significance, and the most striking feature of the *Origin of Species*, the feature which bore down opposition, was the accumulation of facts adduced to support the new thesis. Whence came the facts which first swayed Darwin's mind ? Many he gathered from extraordinarily wide and intensive reading, he himself wrote in his "Autobiography," "When I see the list of books of all kinds which I read and abstracted, including whole series of Journals and Transactions, I am surprised at my industry" (*Life and Letters*, vol. I, p. 83). But the first facts came from the materials of the Voyage.

And here I should like to do justice to collaborators with Charles Darwin the influence of whose work upon his views has not received due recognition

There can be no doubt that the foundation of his new ideas rested upon the materials seen in South America and collected in the Galapagos Islands. "In a small diary in which Darwin recorded methodically and briefly the outstanding events of his lifetime, opposite the general entries of 1837, Darwin wrote 'In July opened first Note-Book on Transmutation of Species.—Had been greatly struck from about month of previous March on character of S. American fossils—and *species on Galapogos Archipelago.—These facts origin (especially latter) of all my views*'"[1] (*Diary*, p. 438).

It must be remembered that Darwin at the time of the voyage, a young man of twenty-two to twenty-seven years of age, was not a systematist, although later he became a systematic zoologist of first rank ; and every worker at classification knows that no amount of reading but only the hard school of experience will enable an observer to distinguish closely related species and varieties. It is not surprising therefore to find that Darwin himself did not recognise that the islands of the Galapagos group were tenanted by groups of different but related forms. The fact was pointed out to him by the Vice-Governor, Mr. Lawson, but so little impression did the information make at first, that Darwin actually mingled the collections from two of the islands (*Journal*, Chap. XVII). Fortunately, the collections from the other islands were kept apart, else there might have been no point of origin for the new ideas. But Darwin did not identify these collections, which he gathered so assiduously.

[1] My italics.

The great series of events which happened between the appearance of the two editions of the *Journal*, and which, I believe, supplied the factual basis upon which the ideas of evolution and natural selection grew, was the appearance of the reports of expert systematists (with whom he worked in close contact) upon the materials which Darwin had collected. The second edition contains a longer discussion on reptiles, the elaboration of the botanical and ornithological evidence, and the question of the geographical distribution of the forms is more carefully discussed. Some doubt in the orthodox explanation is expressed in Darwin's conclusion . "Reviewing the facts here given, one is astonished at the amount of creative force, if such an expression may be used, displayed on these small, barren, and rocky islands "

It is a strange comment upon the growth of an idea which transformed the thinking of the world, that it should have rested upon the casual information of the Vice-Governor of the Galapagos Islands, in the absence of which the collections from the different islands would have commingled, and the all-important evidence lost ; and it is a standing monument to the value of the labours of the systematic naturalist.

REVIEWS

MATHEMATICS

Contributions to the Calculus of Variations 1931–1932. Theses submitted to the Department of Mathematics of the University of Chicago. [Pp. ix + 523.] (U.S.A.: University of Chicago Press; Great Britain and Ireland: Cambridge University Press, 1933. 16*s*. 6*d*. net.)

THIS volume contains ten papers on the calculus of variations, nine of them being theses submitted for degrees in the University of Chicago. Professors Bliss and Graves, under whom the work was carried out, maintain that this method of publication has certain advantages. It is true that results proved in the theses are thus made available to others working in the same field. Where a thesis contains results which are new and reasonably important, the German method of publication by the author and distribution only to the universities of his own country has obvious disadvantages. It is annoying to be referred in a later work to an inaccessible thesis. On the other hand, where results are sufficiently valuable, their publication in a shortened form in a standard journal leads to wider publicity than the method in the book under review The argument advanced by Professor Bliss that this involves much condensation under the immediate direction of the supervisor seems rather to support this view than otherwise. Can any mathematician begin to learn too soon the difficult art of describing his results shortly and clearly?

The theses in the book under review deal with varied problems in the calculus of variations. Two of the theses are of an historical nature; in particular, there is a lengthy memoir by R. G. Sanger on the relationship between the theory of functions of lines and the calculus of variations and on the historical development of these relationships.

In one thesis, H. H. Pixley applies the methods of the calculus of variations to determine the rate of production at which a monopolist should operate his business to furnish a maximum profit. We may commend the possibility of work of this type to the consideration of the statesmen of the world. Perhaps the solution of our present difficulties lies in inspired research in the calculus of variations!

E. M. W.

Functions of a Complex Variable. By THOMAS M. MACROBERT, M.A., D.Sc. Second edition. [Pp. xv + 347, with 83 figures.] (London: Macmillan & Co., Ltd., 1933. 14*s*. net.)

THIS is a second edition of Professor Macrobert's widely used textbook. The changes from the first edition are few. The book now includes an

account of the modified Bessel functions $I_n(z)$ and $K_n(z)$, and in an appendix we find a discussion of the analytic continuation and asymptotic expansion of the hypergeometric function.

Very many students owe their introduction to the theory of functions to this useful book. For the benefit of those unacquainted with the first edition, we may remark that the treatment is always clear and straightforward, there is a fine collection of examples scattered throughout the book, and, last but by no means least, a comprehensive index.

E. M. W.

Vector Analysis. By H. B. PHILLIPS. [Pp. viii + 236, with 62 figures.] (New York: John Wiley & Sons, Inc.; London: Chapman & Hall, Ltd., 1933. 15*s*. 6*d*. net.)

THIS book contains an account of vector analysis suited to the requirements of students of theoretical electricity and hydrodynamics. This should supply a definite need, as the development of vector analysis in physics textbooks is usually very compressed and only adapted to the particular type of field considered. Here we have the essential mathematical properties of vector fields treated apart from the physical hypotheses. A study of the book should give the familiarity with the properties of vectors and the facility in use of the notation which is needed by students of physics and mechanics.

The discussion of the continuity of a function and of the convergence of "improper" integrals is adequate for the purpose of the book. An expression of the form

$$\int \sqrt{dx^2 + dy^2 + dz^2}$$

is, however, rather shocking to the pure mathematician; perhaps the readers for whom the book is intended will not be so unduly sensitive.

The author uses the "dot-cross" system of notation.

E. M. W.

Handbook of Mathematical Tables and Formulas. By R. S. BURINGTON, Ph.D. [Pp. vi + 251, with 57 figures.] (Sandusky, Ohio: Handbook Publishers, Inc., 1933. $2.00.)

IN these busy days, when the professional worker must have a wide range of information at his command, handbooks are becoming more numerous as supply meets demand. It is important that the preparation of these handbooks should be entrusted only to those who are masters of the subject, that the criterion for selecting or rejecting contents or arrangements should be the needs of the user, and that no pains should be spared in the compilation or printing.

The first third of the book before us consists of elementary mathematical formulæ. The author has made good use of his space, selecting the formulæ to which reference is most likely to be made. In particular the extended table of integrals, covering more than 300 definite and indefinite integrals, will be helpful to those whose calculus has collected moss since college days. One omission is the general term of series; admittedly the general term of the series for sin x can be inferred, but this is not true of the series for tan x, and the introduction of the first few Bernoulli and Euler numbers would not have been out of place.

Of the tables it is not so easy to write favourably. There are so many tables in existence already that we expect new tables to justify their existence by their merits. A search for evidence of artistry or craftsmanship is disappointing. The reader's intelligence is insulted by splitting 5-decimal numbers into groups of 2 and 3, although it is required to discover that the three columns of numbers on page 228 that are separated by the space of three figures are really parts of a 10-decimal number. We find that cos 0°·1 is 1·0000 but cos 0°·2 is 0 99999, similarly $\sqrt{1}$ is 1 but $\sqrt{4}$, three lines lower, is 2 000. In the tables of logarithms of the trigonometrical functions, differences are provided, but the author is evidently not a user of calculating machines, for he has not sufficient respect for the natural functions to provide them with differences also. In general the cipher that usually precedes a decimal point is omitted, but the supreme example of hesitation is afforded by pages 188–9, on the first of which the sine has a 0 in alternate blocks of five, except for two intrusions, while the cosine is properly equipped in each block, except for two omissions. On the facing page the sine has been favoured, but the cosine entirely stripped of its ornament; on the following page complete harmony has been restored, or rather appears for the first time Small points, perhaps, but straws show which way the wind blows, and points like this show the characteristic of the compiler—careful or otherwise. Some faults can be forgiven, but the omission of the line for 0° on page 242 is irritating, not because we do not know the functions of 0°, but because the blocks of five commence with 1 and 6, whereas established custom has decreed that they shall commence with 0 and 5. The unnecessary omission of characteristics in the logarithms in Table XV is certain to lead the unwary into error. That the author is not accustomed to interpolating with higher-order differences is shown by the fact that he quotes Newton's forward-difference formula, but makes no mention of the much more powerful central-difference formulæ. The tables of the complete elliptic integrals are given with $\sin^{-1} k$ as argument, following Legendre; a table-maker who studied his user would have chosen k^2.

Typographical faults abound. The use of modern face (equal height) figures instead of old style (heads and tails) figures is against the best tabular practice. The repetition of the signs ° ′ ″ throughout a column offends the eye and does not help the mind. The use of 81·0° for 81°·0 cannot be pardoned. On page 192 and elsewhere a rule has mysteriously intruded itself between the lines for 0·49 and 0·50. On page 216 the use of a wide space and a rule between columns 4 and 5 is simply a case of sending two men to do the work of one; the use of punctuation at the end of displayed equations is a further instance of this.

The growing divergence of the English and the American languages accounts legitimately for the interchange of decimal points and multiplication signs, and perhaps also for contractions like csch, which suggests sea-sickness! But it can hardly be stretched to cover such coinages as anti-hyperbolic for inverse hyperbolic, a wavering between antilogarithm (which is correct) and anti-logarithm, the use of an adjective as a noun in "The cologarithm of a number N is the *negative* of the logarithm of N", or "trigonometrical functions in radian measure" for "trigonometrical functions of angles expressed in radians". One of the chief values of mathematics is the training it affords in preciseness, and this preciseness should extend to expression as well as to numbers and formulæ. Finally, the terms *decimal*

fractions and *decimal parts* (of a degree), although undoubtedly current immediately after the introduction of decimals, have now given way to the shorter and sufficient *decimals*.

These criticisms will have served their purpose if they remind those who write that elegance and care are still prized, even in this age of bustle.

L. J. C.

PHYSICS

Heat. By JAMES M. CORK, Ph.D., Associate Professor of Physics, University of Michigan. [Pp. xi + 279, with 115 figures.] (London: Chapman & Hall, Ltd.; New York: John Wiley & Sons, Inc., 1933. 18*s*. 6*d*. net.)

PROFESSOR CORK has attempted to survey a syllabus approximating to that of a modern honours course in less than 250 pages. With this end in view he has omitted the usual detailed descriptions of classical experiments and has shortened the whole treatment, if not to the point of inadequacy, at least to such an extent that the serious reader will continually feel the need for further information. Anticipating this need the author has given references to a well-selected list of original papers which will enable the student who has access to a good library to fill many of the gaps.

An appendix contains tables of data useful in the laboratory or study and a list of "suggestive topics for experimental study." Diagrams and brief hints concerning some of these experiments are scattered through the text, but full descriptions of the construction of the apparatus and of a satisfactory experimental procedure would be very much appreciated in many laboratories.

Students will find the book a helpful addition to a course of lectures, and teachers an admirable outline for elaboration in the classroom. The production is excellent, but the price will put the book beyond the means of most students in this country to whom it would be a luxury rather than a necessity.

D. O. W.

A Text-Book on Heat. By A. W. BARTON, M.A., Ph.D., Assistant Master at Repton School. [Pp. xiii + 378, with 110 figures.] (London: Longmans, Green & Co., 1933. 7*s*. 6*d*. net.)

HERE is an excellent textbook primarily intended for the use of students reading for University Entrance Scholarships or Higher School Certificate examinations, but, in fact, covering a large part of a pass degree syllabus. The style in which it is written is admirably adapted to the needs of the sixth form and although, as the author states in his preface, considerable use has been made of standard works of a more advanced character, there is ample evidence that the text is the result of much individual thought. The treatment of *scale of temperature* on the first page shows that the author knows his subject and he maintains the standard there set up very fairly throughout.

There are a few blemishes: Roy and Ramsden's experiments are described but Bunsen's ice calorimeter is omitted; Newton did not discover his "law of cooling" by experiment; Davy rubbed blocks of ice together in 1799 (or earlier) not in 1812 and the result of the experiment should not have disturbed the convictions of the most lukewarm of calorists; the definition of

entropy is incomplete; thermal conductivity is not defined in words at all, and although there are good accounts of its determination by "academic" methods there are no references to methods used, *e.g.* at the N.P.L., for substances of industrial importance.

Dr. Barton's book is likely to become a school classic and it is clear that he inherits a full measure of the skill for which his father, the late Professor E. H. Barton, was so justly famed. There is an index and a good selection of examples with answers.

D. O. W.

The Cotton Effect and Related Phenomena. By STOTHERD MITCHELL, D.Sc. (Glas.). Lecturer in Physical Chemistry, University of Glasgow. [Pp. viii + 92, with 34 figures.] (London: G. Bell & Sons, Ltd., 1933. 7*s*. 6*d*. net.)

IN physical optics, the Cotton effect is the way in which the rotation and ellipticity of polarised light vary near an absorption band, usually in solutions, but occasionally in crystals. Nearly one-quarter of the book now under consideration has to be read before this fact is revealed; actually the introductory part deals largely with elementary double refraction and kindred subjects which can be found elsewhere in profusion. Once however the author gets to grips with his main theme he has much that is interesting, and not very readily available, to tell us. The instrumental section describing spectro-phomometric methods is particularly well done, and the detailed references will be welcomed. Of value too is the paragraph which treats the behaviour of the few comparatively straightforward inorganic compounds which have been examined: in these there seems some real hope that the results can be interpreted in terms of molecular structure. Much of the organic work suffers from an inveterate pragmatism: with much patience hosts of absorption readings are fitted with meticulous care to varieties of curves scarcely one of which rests upon a sound theoretical basis. Naturally, this is not the author's fault, but it tends to make some portions of his book leave one in the air, asking what the purpose of it all is. The lack of ultimate structural data is very marked; this tends to reduce many pages to a catalogue of observations.

The last chapter is concerned with the construction of models to illustrate the composition of circular vibrations. Educationally it may have its value; philosophically it seems a retrograde motion, taking one back to Maxwellian mechanical concepts of things just incapable of demonstration with wires and rods. Physics has grown up a little since then.

F. I. G. RAWLINS.

The Ostwald Colour Album. A complete collection of colour standards for use in colour specification and the study of colour harmony and in conjunction with Dr. Ostwald's "Colour Science." Arranged by J. SCOTT TAYLOR, M.A. (London: Winsor & Newton, Ltd. 21*s*. net.)

THIS Colour Album gives 680 Colour Standards arranged on twelve plates of convenient form. The number of colours should be sufficient for most needs and, by an ingenious system of numerical and alphabetical classification, it is possible to identify any particular colour at once. The system is absolute and at last colours can be measured with the same accuracy as pitch is given

by musical notes. That is to say, though some delicate gradation of colour —shall we say lavender or a pale ochre—may produce a different psychological sensation in different people, its value in Dr. Ostwald's scale of colour standards remains definitely fixed.

The diagrams of the Monochromatic Triangles make it possible to find the percentage of Black and White in a colour—a most important point. Concise rules are given whereby a group of harmonious colour combinations may be found, the plates being so arranged that the complementary colours are easily recognised along a horizontal line This system also makes it possible to arrive at an appreciation of the complementaries of the shadow colours or Isochromes.

While a series of harmonies is easily arrived at from the charts, one wishes that another important factor, particularly from an artist's point of view, (*i.e.* the Discord), had been gone into with the completeness with which the Chromatic and Monochromatic scales are elucidated ; it may be that we are yet to look forward to this in Dr. Ostwald's second Volume, and there is little doubt that for manufacturers of all commodities dealing with colour, this album is the most perfect that has yet been devised.

F. O.

High Frequency Measurements. By A HUND. [Pp. x + 491, with 373 figures.] (New York and London : McGraw-Hill Book Company, Inc., 1933. 30*s*. net.)

" RADIATION is mostly due to reflections of electromagnetic disturbances traveling along a wire. The reflections generally occur either at the respective ends or at some other place (transformer, etc.). The lines of force are, one might say, snapped off at the end of the line, and electromagnetic waves detach themselves into space just as electrons, which are either accelerated or decelerated, start to radiate energy because a portion of the total field is correspondingly accelerated or decelerated " (p. 2). " The reason metals are good conductors is because we have to deal with atoms only. . . . For further details, see page 262 " (p. 30), and, on p. 262 " Metals have a positive temperature coefficient This means they increase their resistance with the temperature, since, according to the classical theory of conduction by *free* electrons, the conductivity is proportional to the number of free electrons in unit volume, proportional to the mean free path of an electron, and inversely proportional to the mean free path of an electron, and inversely proportional to the absolute temperature." " For complicated aerials, the dipole effect must be extended over the entire aerial, and the radiation effect is found by integration which takes into account the radiations in all directions as well as the retardation time " (p. 399). " The determination of the effective height depends then upon the measurement of ε in microvolts per meter and is carried on the distance d to the receiving aerial in meters (choose d about $5\lambda m$) the sender current I in amperes, and the frequency f in kilocycles per second or the corresponding wave length λ in meters " (p. 402).

These statements are typical of the looseness of expression which is common throughout this book. The present reviewer finds the literary style so bad that he is unable to concentrate on the arguments involved, and therefore cannot criticise the subject-matter. It may be that the author is not familiar with the English language (he has written a book on a similar subject in German). No lack of familiarity with the language, however, can

account for the curious explanations of a flashing neon lamp on p. 53 and of its application to the production of a linear time base on p. 78, or the confusion between "energy" and "power" which occurs in several places.

J. A. R.

Traveling Waves on Transmission Systems. By L. V. Bewley. [Pp. viii + 334, with 133 figures.] (New York: John Wiley & Sons, Inc.; London. Chapman & Hall, Ltd., 1933. 28*s*. net.)

Under the title of *Traveling Waves on Transmission Systems* the author has collected together a fund of information concerning practically every kind of transient disturbance likely to occur in electrical transmission lines and terminal apparatus.

The literature of this subject has grown enormously in the last few years and the author's contributions to it have been substantial. In assembling under one cover and correlating the various works, which are widely dispersed throughout the scientific publications of different countries, the author has given invaluable service.

The book is written primarily for mathematicians, but practical applications are generally kept well in the forefront of the argument. Moreover, many experimental observations made with the kathode-ray oscillograph are given in support of the theories developed In the opening chapter the author establishes the general equations for travelling waves along a twin conductor system, the earth being considered as a zero potential plane. The effect of corona on the normal line constants is noted and the behaviour of travelling waves at transition points is discussed. Attention is drawn to the importance of waves due to lightning and it is pointed out that such waves are generally of simple form enabling them to be represented by the difference of two exponential functions.

Applications of the general theory are then given in some specific cases. This is followed by an illuminating analysis of the effect of corona on wave shape, showing how the crest becomes decapitated and the tail built up. After devoting some space to the manner in which successive reflections occur on short transmission lines, the author considers a number of schemes for the protection of apparatus from the destructive effect of travelling waves. Spark-gaps, lightning arrestors, reactors, thyrite damping resistances are all dealt with in turn.

At this point the author makes a more ambitious analysis of the problem of travelling waves with special reference to multi-conductor systems. He shows how the mathematics can be simplified by resolving the travelling wave into components. The practical case of waves due to lightning is discussed at some length. The formation of a bound charge and the influence of the rate at which the charge is released are matters which are carefully investigated, and the conclusion is drawn that induced voltages are more dangerous to highly insulated lines.

In the next section much valuable information is given about earth wires on overhead line systems and how their situation influences the protection afforded against induced voltages and direct lightning strokes. The value of adequate earthing for the towers supporting the lines is emphasised.

Surges set up by switching operations are analysed and methods of damping them out are given. The action of the Petersen Coil is explained. This concludes Part I of the book.

The second part is rather vague, being mainly concerned with the problem of obtaining suitable mathematical equations to represent the high frequency oscillations and terminal transients manifested by transformers under impact by travelling waves. The relations between the equations derived and the known facts are not always quite obvious.

Lastly the suppression of internal oscillations in transformers by electrostatic shielding is considered and methods adopted in practice for making non-resonating transformers are outlined.

A summary is given at the end of each chapter. This is a most useful feature and helps the reader rapidly to pick out any particular point in which he is interested. There is also a valuable bibliography and an Appendix giving a table of relations employed in operational calculus.

H. M. BARLOW.

Wireless Over Thirty Years. By R. N. VYVYAN. [Pp. xiv + 256, with 16 plates and 12 diagrams.] (London: George Routledge & Sons, Ltd., 1933. 8s. 6d. net.)

THIS book is an authoritative account of the most important developments that have taken place during the last thirty years in the creation and harnessing of electromagnetic waves for communications purposes.

The story is told in a most attractive manner. Technicalities are either avoided or explained with such care that the layman could have no difficulty in appreciating their significance. The task of writing a book of this kind is no small undertaking. To give a properly balanced account of each new development as it came along, keeping it in its right perspective, without ascribing undue weight to any one of the many ramifications of the vast technique which has been gradually built up is indeed a worthy achievement and one of which the author can claim to have acquitted himself most happily. This success is directly due to his great knowledge of the subject, first-hand knowledge of a most intimate nature acquired throughout the period under review.

The book is divided up into twenty-one chapters. Starting with a résumé of the work of early pioneers, the fascinating story of how the first recognisable messages were transmitted across the Atlantic from Poldhu to Signal Hill, Newfoundland, on December 12, 1901, is told with beautiful simplicity. The immense sensation caused by this achievement led to rapid developments and the author proceeds to unfold the subsequent history of the establishment of commercial trans-atlantic and other radio links throughout the world. Thus, the introduction by the Marconi Co. of the short-wave Beam System and the organisation of a chain of stations for Imperial Wireless communications is traced in all important details. The author shows how London has become the central exchange for the communications network of the world, a coveted position which was secured for us by the foresight and industry of our Post Office Engineers.

Up to this point, every page of the book is of absorbing interest and few, if any, suggestions could be made for improvement. The section which immediately follows, consisting of four chapters dedicated to wireless in the War, is mainly concerned with matters which, although of considerable importance, seem foreign to the main theme. Much space is devoted to tactics in war as they affect wireless communications and repetition is not an

infrequent occurrence. A single chapter would have sufficed to cover the relevant matter with which the author deals.

The next section describes systems for communications at sea and in the air. Attention is drawn to the great value of wireless direction-finding and to the splendid services rendered day and night by those invisible lighthouses known as wireless beacons surrounding our coasts.

There is also a chapter in which the author relates the history of contributions made by British Post Office Engineers to wireless technique. Few people probably appreciate the full value of the work of these men in helping to bring about the degree of perfection attained to-day in our communications system. For example, many professional wireless engineers and amateurs who are accustomed to handle wave filters do not know that this invaluable device was invented by a member of the Staff of the British Post Office.

Commercial wireless telegraph development in its many and varying aspects is reviewed with admirable understanding. The pressing problem of ether congestion is discussed and possible future developments to ease the situation are indicated. Broadcasting is also dealt with separately and the special considerations which it involves are outlined.

Finally, the author draws on his unique experience to give some advice to those desiring to become wireless engineers. He explains the exacting qualifications required for success both in the field of research and production. Attention is drawn to some of the problems for the future and the type of mind that is required to tackle them. He points out that engineers suitable for research work are born, not made, that there is a wide divergence between knowledge of the facts of science and the methods of their application, between the power of one man to use an invention and another to use a principle for the purpose of fresh discovery.

This section is, perhaps, outside the legitimate scope of a history of wireless, but it forms an appropriate ending to the book and emphasises the masterly grip which the author has of all matters pertaining to his subject.

H. M. Barlow.

Theory of Thermionic Vacuum Tubes. By E. L. Chaffee. [Pp. xxiv + 652, with 360 figures and 6 plates.] (New York and London: McGraw-Hill Book Company, Inc., 1933. 36*s*. net.)

In the first five chapters of this book a very full survey of the fundamental action of vacuum tubes is given, and the underlying physical facts are described in detail; in particular the various types of filaments are discussed in a complete manner. The triode is then discussed and it is shown how its behaviour may be described in terms of certain equivalent circuits; to this end the well-known equivalent-plate-circuit theorem and a less well-known equivalent-grid-circuit theorem are proved—the latter apparently has not been stated before. The use of triodes in all types of amplifiers, and as oscillators and detectors is treated very fully from a theoretical point of view by using the equivalent circuits. A special symbolic nomenclature is developed for this part of the work which considerably simplifies the mathematical arguments. The last chapter is concerned with tetrodes and pentodes, again from the "equivalent circuit" aspect.

The book contains a very complete account of the action of vacuum tubes and in particular of their behaviour when associated with outside circuits. The method of presentation, involving the special nomenclature, is original

and very concise. Parts of the book not directly connected with the author's own work are not so complete as they might have been, in particular we may instance the fact that there is no mention, in a chapter dealing with non-linear circuits, of the fundamental work of Appleton and Van der Pol; and that the name of Moullin does not occur in a six-page treatment of vacuum tube volt-meters. The book is confined to low power tubes. In the preface we are led to expect a second volume dealing with power tubes and soft tubes. Let us hope it reaches the high standard of the present volume.

J. A. R.

Experimental Atomic Physics. By G. P. Harnwell, Ph.D., and J. J. Livingood, Ph.D. [Pp. xiii + 472, with 175 figures.] (New York and London: McGraw-Hill Book Company, Inc., 1933. 30*s*. net.)

It might be supposed from a glance at its title that this book is only a laboratory manual to enable teachers of physics to incorporate modifications of some of the more fundamental experiments in modern physics in their courses. Information to this end is certainly to be found within its covers, but, in addition, the authors have sought to render an account of the accurate determinations of the constants required in atomic physics. In this connection, their good critical survey of the methods of measuring e/m for electrons and positive ions—from which only a reference to the work of Conrad and Eisenhut is missing—might well be cited as an example.

The book opens with a chapter on physical units and on the properties of radiation, black body radiation being discussed in the second chapter. Work on the atomicity of electricity and on the determination of e is dealt with in the next chapter, where some mention of Bäcklin's experiments would have been appropriate. The determinations of e/m are described in the fourth chapter and the wave aspects of matter are discussed in the fifth. Thermionic and photoelectric effects are described from a modern point of view in a sixth chapter, where the prevailing fashion of omitting descriptions of the early and fundamental experiments in these subjects is followed. Line spectra and atomic energy states are treated with exceptional clearness in subsequent chapters, where also good accounts of experiments in X-rays and radioactivity are given.

In appendices are given descriptions of instruments for measuring small currents and potential differences and of vacuum technique; a table of fundamental physical constants and a periodic table are also given. The book is excellently printed, the figures are very adequate and the number of references to individual pieces of research is unusually large. It should prove a most useful book to teachers of advanced physics.

L. F. B.

Collision Processes in Gases. By F. L. Arnot, B.Sc., Ph.D., Lecturer in Natural Philosophy in the University of St. Andrews. Methuen's Monographs on Physical Subjects. [Pp. viii + 104, with 37 diagrams.] (London: Methuen & Co. Ltd., 1933. 3*s*. net.)

This monograph is divided into two parts. The first deals with collisions between electrons and atoms, and will be found particularly useful for its clear account of certain problems, such as the probability of the excitation of an atom by electron bombardment and the angular distribution of the

scattered electrons, on which information is not readily accessible to the general reader.

The second part deals in a brief but satisfactory manner with collisions between photons and atoms, and also with collisions of the second kind.

L. F. B.

CHEMISTRY

Introduction to Physical Chemistry. By F. B. Finter, M.A. [Pp. xv + 276, with 4 plates and 48 text-figures.] (London: Longmans, Green & Co., 1933. 6s.)

This is a revised edition of a book first published in 1926; it is stated to be sufficiently elementary for any boy who has reached the standard of the School Certificate, and is intended to cover the ground required for Higher Certificates and University scholarships, but in the reviewer's opinion it falls short of this aim.

The author has interpreted his statement in the preface that "it is of course futile for a boy to read physical chemistry unless he is learning physics as well" all too literally. There is no mention of the Laws of Thermodynamics, of the kinetic theory, of the relation between the structure of molecules and their physical properties, or of the electromotive forces in a cell. That it is possible to treat these subjects in an elementary way intelligible to boys of 17 is apparent from certain other books which succeed admirably in doing so. The omission of all topics which border particularly nearly on Physics is surely also dangerous on other grounds, the obvious undesirability of dividing different branches of science from each other being one, and the other perhaps more serious one is that students who are primarily interested in biology are not likely to have done enough Physics to ensure an adequate grounding in such subjects The omission of any account of the simplest form of electrode potential measurement seems particularly unfortunate in this respect.

The author makes his points clearly and accurately and mentions a large number of useful exercises and demonstrations which might well be helpful to any school-master, and it is particularly to such teachers that this book can be recommended. For a young student it is too unbalanced and there are too many questionable points, as for example the author's apparent reluctance to accept the fact that all reactions are at least theoretically reversible, for him to use it as his sole textbook of Physical Chemistry. The book is quite well produced, but some of the diagrams, particularly those illustrating standard apparatus, seem to smack of a bygone age.

O. H. W.-J.

Physical Chemistry, for Students of Biology and Medicine. By D. I. Hitchcock, Ph.D. [Pp. xii + 182, with 26 figures.] (London: Baillière, Tindall & Cox, 1932. 15s. 6d. net.)

This is a short textbook of certain aspects of Physical Chemistry of special interest to biological students. It is stated in the preface to the book that the material it contains has been given as a course of lectures to students of Physiology at Yale during the last five years, so that it is clear that the author has had experience of which branches of the subject are of most practical interest to students of medicine. There are now several books

written on this subject with this purpose, and this one is likely to be as useful as any of them.

Chapters are included on the general properties of liquids, gases and solutions, and there is, naturally, a long section on Hydrogen Ion measurements which should be particularly valuable. A shorter section on colloids and adsorption processes suffers rather from over-condensation, but it is satisfactory to see that the author has been able to give a useful and elementary account of membrane equilibria and of the kinetics of enzyme reactions. The last chapter of only six pages on elementary thermodynamics is too short to give any idea of the subject, and should probably therefore have been omitted.

The book covers most of the ground that is of obvious importance to young biologists, but as has been implied above it is in places so condensed as to miss out some important applications, though this defect is remedied to some extent by the incorporation at the end of the chapters of a fair number of exercises to be worked by the student. The short biographical footnotes are likely to interest the readers of the book, and are accurate if naïve.

The book is well printed, but the price is too high.

O. H. W.-J.

Organic Syntheses: Vol. XIII. W. H. Carothers, Editor-in-Chief. [Pp. viii + 119.] (New York: John Wiley & Sons, Inc.; London: Chapman & Hall, Ltd., 1933. 10*s.* 6*d.* net.)

In this volume full descriptions are given of tested methods of preparation of allantoin, azelaic acid, 2-phenyl-4-(3′-4′-dimethoxybenzal)-oxazolone, benzalphthalide, β-benzoylpropionic acid, *n*-butyl borate, *iso*-butylbromide, butyroin, *m*-chlorobenzaldehyde, 1 : 4-dibenzoylbutane, 2 : 4-dinitrophenylhydrazine, diphenyl triketone ethoxyacetic acid, fluorobenzene, *p*-fluorobenzoic acid, methoxyacetonitrile, methyl iodide, α-methyl-α-phenylhydrazine, methyl isopropyl ketone, 1-nitro-2-acetylaminonaphthalene, 2-nitrofluorene, 2-aminofluorene, 1-nitro-2-naphthol, N-nitrosomethylaniline, nitrosomethylurethane, perbenzoic acid, *o*- and *p*-propiophenol, *o*-toluamide, sym-tribromobenzene, tricarbomethoxymethane and veratric aldehyde. In an appendix are given later references to preparations in preceding volumes.

The usual treatment has been followed, a section on procedure recommended for the preparation, notes and finally references to descriptions in the literature. This series is now so well known as to need little recommendation or comment, but it is surprising that no mention is made of Perkin and Robinson's detailed description of the preparation of veratric aldehyde when the method recommended resembles theirs so closely.

O. L. B.

Industrial Chemistry. By W. T. Read. [Pp. viii + 576, with 130 figures.] (New York: John Wiley & Sons, Inc.; London: Chapman & Hall, Ltd., 1933. 31*s.* net.)

"Students preparing for a career in chemical industry need a broad picture of all those industries concerned with chemistry. . . . Teachers of chemistry in high school and college should be sufficiently familiar with chemical industries to give accurate information about essentials. . . . Business men are often in need of condensed information about a process or a product.

. . . This book is written with a view to meeting the needs of all these classes of readers."

The result is a "broad picture" of chemical industry, painted more after the manner of the scene-painter, presenting much effective contrast but lacking detail. The book abounds in well-constructed outline pictures of different processes which can be regarded with great interest by anyone outside the industry and, therefore, in the rôle of onlooker rather than performer. This pictorial quality, while investing the book with a certain fascination, reduces its value both for the student preparing for a career in chemical industry and for the business man in need of condensed information

The value of the book would be greatly improved by the inclusion of carefully selected references to papers and books in which more detailed information can be obtained. An inevitable weakness in a book of this character is the lack of references to those quantitative considerations of plant design and operation which mean everything to the successful development of a process. The book is remarkably well illustrated by line drawings and diagrams of individual plant units, as well as of more complicated plant lay-outs required for complete processes. In short, it is a first-rate picture book of the chemical industry and, as such, should find a definite place upon the bookshelf of those for whom it is specifically written. Even the chemical engineer, to whom the book will appear to be so elementary as to be almost trivial, can derive great enjoyment and inspiration from a perusal of its pages.

W. E. GIBBS.

Catalysis and its Industrial Applications. By EDWARD B MAXTED, D.Sc. (Lond.); Ph.D. (Berlin), F.I C. [Pp. xii + 530, with 222 tables and 66 illustrations.] (London: J. & A Churchill, 1933. 36*s*. net.)

THE present century has witnessed a great development in our knowledge of the mechanism of catalytic phenomena. Even more striking has been the success with which this information has been applied industrially and with which a corresponding operating technique has been developed. Evidently, catalysis, like electricity, "has come to stay"! It is significant that a lectureship in this subject has recently been established in the University of Bristol, and it is fortunate that so distinguished a worker in the field as the author of this book should be the first holder of this lectureship.

Those of us who are interested in the industrial development of chemical processes, as well as those who are interested in all chemical processes for their own sake, will find in this very substantial book a thoroughly adequate and well-presented account, not only of the present conception as to the mechanism of catalytic reactions, but also of the industrial use that is made of catalytic processes in various fields. After a series of chapters dealing with such theoretical considerations as the kinetics of catalytic processes, the effect of external factors upon catalytic activity, the relation between adsorption and heterogeneous catalysis and the methods of preparation, as well as the principal uses, of the commoner catalysts, we are introduced to the different types of catalytic reactions, grouped under four headings: hydrogenation and reduction, oxidation, processes depending upon the addition or separation of water and, finally, miscellaneous reactions such as halogenation, sulphonation, nitration, etc.

The second part of the book is concerned with industrial applications of catalysis and consists of five chapters dealing, respectively, with ammonia synthesis, oil hydrogenation, ammonia oxidation, contact sulphuric acid, and processes connected with fuel, including, *inter alia*, coal hydrogenation, synthetic methyl alcohol and the manufacture of hydrogen from water gas. These industrially important reactions are well described, due emphasis being laid upon the engineering and economic factors which play so large a part in determining the success of any industrial process.

This is a notable and timely book of the greatest interest to all who are concerned with the technical development of industry, particularly in these days when catalytic processes have become numerous and important. It can be recommended to those who seek to acquire a general knowledge of the subject, as well as to those who wish to obtain special information relating to some particular aspect of it or of some particular process. The value of the book for reference purposes is greatly enhanced by the large number of references to the original literature which are included in every chapter.

W. E. GIBBS.

A Textbook of Fire Assaying. By EDWARD E. BUGBEE. Second edition. [Pp. xii + 299, with 51 figures.] (New York: John Wiley & Sons, Inc.; London: Chapman & Hall, Ltd., 1933. 18*s*. 6*d*. net.)

THIS is the second edition of a book originally intended for use at the Massachusetts Institute of Technology. It is stated in the preface that, although primarily intended as a college textbook, it is not entirely elementary in character and it is hoped that it will be found sufficiently complete and fundamental to be of service to the more mature student of the science. It is further stated that every effort has been made to avoid the "cook book" method of presentation.

The author presents the subject to either the beginner or the more expert in a very complete yet attractive manner. After having discussed assay materials, furnaces and furnace-room supplies, he proceeds to the question of sampling, devoting a chapter of 31 pages to this most important matter. The subject of assaying proper is commenced by cupellation, followed by parting, then the scorification and crucible assays. The crucible assay, as is customary in America, is preferably to be made in the muffle furnace.

Great attention is given at all stages to the details of both the chemical reactions and the manipulative work, indeed, considerable space is devoted to the discussion of charges and slags.

The treatment of complex ores, assay of lead, gold and silver bullion is considered in the same exhaustive manner. The book ends with a new chapter on the metals of the platinum group, this addition markedly increasing its value as a work of reference.

E. W. YEOMAN.

Principles of Fruit Preservation: Jam Making, Canning and Drying. By T. N. MORRIS, M.A. [Pp. xiii + 239, with illustrations.] (London: Chapman & Hall, Ltd., 1933. 15*s*. net.)

THIS book is one of a series of monographs on applied chemistry issued under the general editorship of Dr. E. Howard Tripp; it is the outcome of nine years of research and factory experience in the Fruit Preserving In-

dustry and five years' research on the special problems of fruit canning in connection with the Low Temperature Research Station at Cambridge. The book is divided into four parts which deal respectively with Jam and Fruit Jellies, Canning of Fruit, Dried Fruits and Considerations Common to all Preserved Fruits. Following on an introduction dealing with the general composition of fruits together with quantitative figures for a number of such as are commonly used in jam manufacture, the first chapter is devoted to a description of the chemistry and preparation of the pectic substances of plants. The second chapter, entitled the pectin-sugar-acid gel, gives a clear account of the somewhat puzzling relationship between the three components of the mixture and brings out clearly the importance of the hydrogen ion concentration as a determining factor in the ability of a pectin sugar solution to form a gel. The significance of a clear understanding of the conditions governing the formation of such gels to jam manufacturers is rendered obvious by the author's description of jam as consisting of fruit tissues embedded in a reasonably firm pectin-sugar-acid gel. The pectose and pectin content of fruit being at a maximum when the fruit is just reaching maturity, it is all-important that the fruit should not be over-ripe; to secure this end and at the same time to ensure smooth and continuous working of large quantities of fruit in the hot season the jam-maker has recourse to cold storage or freezing; the conditions applicable to different fruits are set forth in Chapter III as are also the uses and limitations of sulphurous acid as a preservative. In this chapter are also given the standards for various kinds of jam agreed upon by the Food Manufacturers' Association in collaboration with the Society of Public Analysts.

In view of the growing industry of canning, a comparatively recent development on a large scale in this country, Part II of this book is of special interest; following a general account of the process is a chapter on types of spoilage and corrosion and one dealing with the examination of canned fruits for factory control and diagnosis of the cause of spoilage; the latter involves an analysis of the gas contained in the headspace above the syrup and numerical data of typical analyses are given. In connection with the drying of fruits a chapter is devoted to the Principles of Dehydration; this deals with the various factors which influence the rate of drying, such as the velocity and direction of the air current, etc., etc. The last two chapters deal with the discoloration in fruit products and vitamins in canned and dried fruits. The book contains a great deal of information of general interest, and the presentation is throughout lucid and informative; the reader in search of a concise account of the subject of fruit preservation will have reason to be grateful to the author for supplying him with a very useful text and a considerable bibliography for further reference.

P. H.

Infra-red Photography. By S. O. Rawling, D.Sc., F.I.C., F.R.P.S. [Pp. x + 56, with 12 plates and 17 figures.] (London and Glasgow: Blackie & Son, Ltd., 1933. 3*s.* 6*d.* net.)

This is an essentially practical manual which should be of service to all interested in the use of photography for scientific purposes. An account is given of the infra-red sensitive plates available in commerce and of their handling together with information on filters, focusing and exposure. The most interesting part of the book is devoted to the very varied applications

of this new technique which open up great possibilities to the scientific worker, to the manufacturer and to the archæologist. Infra-red photography can be applied to textiles for the differentiation of blacks, blues and greens, to palæography for the deciphering of obliterated manuscripts, to astronomy for the photography of stars hidden behind nebulæ, to medicine for the revelation of varicose veins beneath the surface of the skin, to photomicrography for the revelation of fine detail in opaque objects and the photography of distant objects normally veiled by haze. There is no doubt that the infra-red sensitive plate will prove of great value to the research worker in many fields and the perusal of this little book should suggest to the thoughtful reader ways of turning this method to advantage in his own field.

O. L. B.

Practical Physiological Chemistry. By S. W. Cole, M.A. Ninth edition. [Pp. xii + 419, with 71 figures.] (Cambridge: W. Heffer & Sons, Ltd., 1933. 12*s*. 6*d* net.)

The reviewer of this well-known and highly popular textbook does not require to emphasise its merit. Attention may, however, be directed to the fact that it is now in its ninth edition and that the last edition, published in 1928, had already been out of print for about a year. Most new editions of a textbook, especially one which deals with a rapidly growing subject like biochemistry, are characterised by additional paragraphs, extra pages and higher price. This volume happily forms an exception to the rule. Though in some parts additional matter has been added and certain important subjects dealt with rather more fully, in other sections judicious compression has been effected so that the size of the book has been reduced and the price lowered. The most conspicuous cut has been the omission of the chapter on blood coagulation; in the words of the author: "despite the fact that my old friend, Professor J. Mellanby, wrote a new chapter for me, I still feel that the subject is not yet suitable for treatment in a book of this description." Though this is primarily a practical textbook each chapter contains a theoretical discussion of its subject-matter. This gives it value as a simple but comprehensive summary of biochemical knowledge. In the present revised and largely rewritten edition, this feature is not less prominent.

W. O. K.

Qualitative Analysis. By H. S. Moodey, M.A. [Pp. x + 182, with 15 figures.] (London: William Heinemann, Ltd., 1933. 5*s*.).

There has long been a real need for a textbook on the theory of analysis suitable for students preparing for the intermediate B.Sc. or similar examinations and published at a modest price, and the author has made an excellent attempt to fill this gap. The book is divided into two parts, (i) theoretical bases and (ii) systematic qualitative analysis. Part I covers the usual ground—the law of mass action, the nature of solutions, the ionisation of water, chemical affinity, etc., and with the possible exception of a short chapter on modern developments of chemical theory, there is nothing which an intelligent student cannot assimilate with ease and profit. In Part II the theoretical aspect is also emphasised. Occasionally the working details are not quite so explicit as is desirable and the choice between alternative methods is, perhaps, too often left to the student. In fact, alternative group separations and confirmatory tests are given so generously that a beginner might easily be discouraged

by the apparent complexity of qualitative analysis. The "spot tests," using ammonium carbonate, ammonium sulphide and potassium iodide, are interesting and the list of organic reagents used in inorganic analysis very useful. The "drop analysis" methods of Feigl are mentioned and this new technique might with advantage have been allotted more space. The book is well produced, exceptionally cheap and may be recommended to all students who wish to know not only what to do but also why it is done.

J. N. S.

GEOLOGY

Historical Geology. By RAYMOND C. MOORE, Ph.D. [Pp. ix + 673, with 413 figures.] (New York and London: McGraw-Hill Book Company, Inc., 1933. 24*s*. net.)

THE book is essentially a work on the stratigraphy of the United States of America and will appeal to American students rather than to those in England.

There are several novel features in the treatment of the subject which is perhaps the main justification for adding another textbook to the long list which already exists.

The most striking novelty is that the palæontology is entirely divorced from the stratigraphy. The rock succession and physical conditions of deposition of each system is considered as developed in its various outcrops on the North American continent and the relationship of the sedimentation in each basin to its neighbour is noted with a statement of the direction from which the waters invaded the basin The evidence for this however is to be deduced, in the main, from the fossils found in the rocks, but nowhere in the book is this evidence given, neither is there any palæontological evidence for the correlations which are made.

Palæontology is only considered in its broadest lines, not even by systems but only by eras. This treatment of the fossil evidence is sufficient to give a very general idea of the main trend of evolution throughout geological time but hardly appears adequate for a book on stratigraphy. It tends to make a student consider palæontology as a biological subject only with no particular value or interest to the stratigraphical geologist.

An excellent feature of the book is that each chapter ends with a good summary and throughout it is well illustrated with good block-diagrams and figures.

W. K.

BOTANY

Index Kewensis Plantarum Phanerogamarum. Supplementum octavium. Edited by Sir A. W. HILL. [Pp. iv + 256.] (Oxford: at the Clarendon Press; London: Humphrey Milford, 1933. £3 15*s*. net.)

WE welcome the appearance of the eighth supplement of the Kew Index which covers the period from the beginning of 1926 to the end of 1933. Once again botanical systematists are indebted to Sir Arthur Hill and his collaborators, Miss M. L. Green and Dr. Sprague, for their devoted efforts in a work of first importance to taxonomists and indeed so indispensable a tool that it is too often taken for granted without due appreciation of the labour that has

gone to its production. The arduous character of the task involved in the present supplement can be gauged by the fact that these pages must contain over ten thousand references. The format and printing conform to the high standard of the Press from which the work emanates.

E. J. S.

British Economic Grasses: Their identification by the leaf anatomy. By S. Burr, M.Sc., and D. M. Turner, B.Sc. [Pp. 94 with 111 figures.] (London: Edward Arnold & Co., 1933. 10s. 6d. net.)

Every student of vegetation from whatever point of view sooner or later comes to realise the necessity for recognising species by characters of the vegetative organs. The experienced worker is aware that the surest means of identification depends on an aggregate of features difficult to define and the appreciation of which is the outcome of long experience. Nevertheless, by means of more tangible characters it is possible to identify many species on leaf characters alone. Keys to the vegetative characters of British grasses have been prepared by more than one author of whom Marshal Ward and Armstrong may be cited. The value of the ligule in this connection has long been recognised, though our rather limited knowledge of the change of form of the ligule with the age of the plant, which is often appreciable, limits its utility.

The present work is of restricted scope, being confined to economic British species. But, as a wide interpretation is given to this term, some sixty-three species and varieties are included. Two keys are provided, the one based on morphological characters and the other on anatomical, but the chief feature is the series of illustrations, from original drawings, which portray the anatomical features of grass leaves as seen in transverse sections, admirably reproduced on thirty-three full-page plates.

It would have facilitated the use of the accompanying descriptive matter if the more distinctive features of each species had been rendered conspicuous. Some indication of the degree of variation in anatomical structure to be expected under extreme environmental conditions would have materially added to the value of the data furnished. The magnification of many of the figures is stated, but no measurements are embodied in the text where relative terms as to size are employed; a type of description often used in the past but rarely satisfactory. The work is admirably produced and moderately priced and should form a useful atlas for students of British Grasses generally.

E. J. S.

Freshwater Algæ of the United States. By Gilbert M. Smith. [Pp. x + 716, with 449 figures.] (New York and London: McGraw-Hill Book Company, Inc., 1933. 36s. net.)

This admirable account of the fresh-water Algæ of the United States is a very welcome addition to algological literature embracing over 400 genera of each of which a description is furnished together with an illustration of one or more species in each. The diagnoses are clear if perhaps a trifle diagrammatic.

A novel feature is the provision of a key to all the genera, in which the use of reproductive characters is reduced to a minimum so that material which is entirely vegetative can in most instances be identified. The salient

characteristics of the constituent species are mentioned in the case of the smaller genera and in the larger those of a few selected types.

Amongst the more interesting species confined to the United States may be mentioned the Volvocine *Platydorina caudata* with its remarkable flattened and twisted colony, and the Floridian *Tuomeya fluviatilis* like a cartilaginous *Batrachospermum*, both of which are the sole known representatives of their respective genera. The genus *Œdocladium* includes four species of which one, the first to be described, was found by Stahl in Germany, and the other three are confined to the Atlantic states.

The peculiar distribution of some fresh-water Algæ, such as *Frulæa*, only known from Germany and one locality in California, or *Dicranochæte* which is rare and local both in Europe and America, may be an indication of erratic and long-distance dispersal. But the significance of such remarkable distributions cannot be assessed until the field has been more fully explored. The production of such a work as that before us is calculated to promote investigation which will not only increase our knowledge of the algæ themselves but at the same time shed light on the general problems of their morphology and distribution.

The author adheres to the view that the genera *Glœochæte* and *Glaucocystis* are members respectively of the Tetrasporaceæ and Oocystaceæ in association with blue-green algæ, in which latter group they are however placed.

The value of the work is enhanced to no small degree by the very full bibliography and the provision of a not inadequate index. The work is admirably produced and the figures mostly excellent.

E. J. S.

Phytopathological and Botanical Research Methods. By Thomas Elsworth Rawlins. [Pp. ix + 156, with 3 illustrations.] (New York: John Wiley & Sons, Inc.; London: Chapman & Hall, Ltd., 1933. 15*s*. 6*d*. net.)

In the preparation of this book the author has covered a wide field in botanical technique as applied to plant pathology. After indicating the best procedure for choosing and planning an investigation, he devotes about half the text to details of microscopical methods: this section deals with the preparation of material for examination with the microscope, and also contains a fairly detailed section on microchemistry, including methods for the identification of crystals: such subjects as photomicrography and dark field illumination also receive attention. Methods of culturing plant parasites are then dealt with, followed by a chapter on the technique for the study of virus diseases and finally a section on statistical methods.

It is unfortunate that certain sections of the book are so brief that they are sometimes difficult to follow. Brevity is perhaps unavoidable when so much ground is covered in some hundred and fifty pages: since however the book is most likely to be used by the specialist or at least by those with some botanical training, rather than by the student, it might have been preferable to omit certain of the more elementary sections, such as those dealing with freehand section cutting and micrometry, in order to allow more space for the treatment of such matters as virus studies and statistical methods.

The book should, nevertheless, prove invaluable as a laboratory companion to the plant pathologist, while botanists in general will find much useful information in its pages. The author has gone to the trouble of trying

out numerous methods, and has included only those which he has found satisfactory. This feature, together with a classified bibliography of over 1,000 references, greatly enhances the value of the book.

F. W. J.

ZOOLOGY

An Introduction to Zoology. By Z. P. METCALF, D.Sc. [Pp. xx + 426, with 180 illustrations and 5 diagrams]. (London: Baillière, Tindall & Cox, 1933. 20*s*. net.)

THIS book is intended as an introduction to zoology for students taking up the subject from the beginning. It is based on the course given at the North Carolina State College and approaches the subject through a single type, the rat. This novel approach to the whole field of zoology through a mammalian type provides an interesting experiment in the method of presentation. The rat is described in some detail and is compared to man in particular as well as to the other vertebrates. Structure is stressed sufficiently for the understanding of function, which is the main theme. The book is divided into three parts. The first is a general introduction to the field of zoology and the animal kingdom. The second and largest part is devoted to the morphology and physiology of the rat and of other vertebrates as compared to it General sections of the chief functions follow those on the special systems. Thus the chapters on the muscular and skeletal systems are followed by one on locomotion in animals, and those on the alimentary, respiratory, excretory and circulatory systems by a discussion of metabolism in general. The third part of the book deals with the broader aspects of zoology such as distribution, palæontology, evolution and the history of zoology and attempts to relate these to everyday affairs. The book provides an original and interesting introduction to zoology, but one which is not easily adaptable to the system on which the subject is usually taught in this country.

F. W. R. B.

Economic Mammalogy. By J. HENDERSON and E. L. CRAIG. [Pp. x + 398.] (London: Baillière, Tindall & Cox, 1932. 26*s*. net.)

THIS book has been prepared for the purpose of bringing together and condensing into compact form as much as possible of the information concerning the economic relations of mammals, the fullest details being of the American species. The literature of economic mammalogy is very extensive, but as it is scattered in books, magazines, journals and pamphlets this volume serves a real purpose and fully justifies itself. Throughout, numerous references are given as footnotes and these are collected in the twenty-five closely printed pages of Bibliography, where they are arranged alphabetically under the authors' names. This documentation and the complete and liberally cross-referenced index enables the reader to make full use of the wealth of interesting information provided. There are no illustrations.

The book is divided into two parts: Part I (pages 3–184) consists of General Discussion where among the twenty-seven chapters are those entitled: III. The Economic Relations of Mammals in General; IV. The Balance of Nature; V. Mammals as a Source of Food; VI. Mammals as a Source of Valuable Products Other than Human Food; X. Domesticated Mammals;

XII. Diseases and Parasites of Mammals, including Poisoning from Plants; XIII. Mammals as Disease Carriers; XVI. The Relation of Mammals to Soil Turnover, Erosion, Dams, etc; XVIII. Mammals as Scavengers; XIX—XXIII. The Economic Relations of Mammals to Birds, Fishes, Insects and Other Vertebrates and Invertebrates. In addition to all this such topics as the extinction of certain species, protection, control and legislation concerning animals are discussed.

Part II (pages 187–347) is a Systematic Discussion and here under the Orders of Mammals the reader will find information about the food, habits, enemies, prey and parasites of mammals, the economic use made of the various species and interesting statistics with regard to fur, leather, wool, horn, ivory, oils, bone, milk and many other products.

P. C. E.

Fishes: Their Journeys and Migrations. By LOUIS ROULE, Professor at the National Museum of Natural History, Paris. Translated from the French by CONRAD ELPHINSTONE. [Pp. x + 270, with 54 illustrations.] (London: George Routledge & Sons, Ltd., 1933. 12*s*. 6*d*. net.)

"THESE dumb fishes, with their tight-closed mouths and their big open eyes. . . . Their action, so varied in its extent and in its countless manifestations, so perfectly adapted to its surroundings, seems to be the consequence of a series of remarkable adjustments. . . . When they journey, they do so with certainty, with precision, as though they well knew the road they travel and what they appear to wish to find on it . . ."

Perfect though these actions seem to be, Professor Roule is not prepared to ascribe them to a reasoning intelligence in the fish, nor is he willing to dismiss them by merely pronouncing the word "instinct." Instead, he develops the conception of a fish as a kind of living robot animated by "Living Nature." This is what he says: "Nature guides and counsels, and her counsel has the force of law She favours her creatures on condition that they observe her rules and hear her voice. The trout hear it as they go up the streams; they obey it when they put themselves into due relation with the water that surrounds them. The action of their environment takes the place of any foresight on their part. When they go on their wedding journey they have no need of knowledge. It is sufficient for them to feel, and to allow themselves to go where satisfaction is promised them: an immanent law leads them to the place where they must go."

Many will wonder whether Professor Roule really believes in "Living Nature" as an actuality, or has written a fable in order to piece together the many observations he has to relate concerning the journeys of fishes. If he is sincere in his belief in a controlling influence, it is difficult to see in what manner "Living Nature" is different from or an improvement upon "God." If, on the other hand, he is convinced that the migrations of fishes can be accounted for solely as the result of their reaction to external environment, why has he buried the evidence in a tedium of irrelevant teleological conversation? Taken from its setting, the evidence he gives is of great interest to the student of natural history. The salmon, for example, is led unerringly from the sea to its spawning-place at the head of the river because it is compelled by its immediate bodily needs to seek out more and more highly oxygenated water, while the smolt comes down to the sea to escape

from the too bright light of the waters in the stream. The fish is said to be "polarised" with respect to the characters of the waters in which it lives, and the extent and nature of the polarisation is dependent upon the phase of life of the fish. And each species has its characteristics. Thus, the shad and tunny are guided by high temperature, the mackerel by temperature and salinity, and so on. Undoubtedly, the author has accumulated a wealth of valuable information on movements of fishes in general, and pointed the way towards a solution of problems still unsolved. But he has yet to tell us what he really means by "Living Nature."

E. F.

British Beetles: Their Homes and Habits. By NORMAN H. JOY. [Pp. xii + 147, with 31 plates and 21 text-figures.] (London and New York: Frederick Warne & Co., Ltd., 1933. 5*s*. net.)

THIS book is intended to encourage the beginner in the study of the life histories of British beetles and is written in a friendly, chatty style. Descriptions of species form the bulk of the book and follow on after short chapters on how to find and capture beetles, how to deal with them after capture, the life history of a beetle and how to name them. A pleasing feature throughout the book is the emphasis laid on the immature stages and their habits. There is also an adequate index.

The four plates of photographs by Hugh Main illustrating the life history of four kinds of beetles are good. The rest of the plates consist of enlarged figures of adult beetles taken from the author's *Practical Handbook of British Beetles*. These are certainly admirable for persons acquainted with beetles, but would not natural-size photographs have been more attractive and helpful to real beginners? We are thinking of the plates, which we prefer, in Sharp's *Common Beetles of our Countryside*. The text-figures of larvæ are mainly taken from Reitter's *Fauna Germanica*.

Undoubtedly the book is a useful attempt in the right direction in spite of some inaccuracies; for example, it is not in the *larval* but in the *adult* stage that the Mangold flea-beetle is to be considered as a pest.

H. F. B.

Cytological Technique. By JOHN R. BAKER, M.A., D.Phil. [Pp. xi + 131, with 3 figures.] (London: Methuen & Co., Ltd., 1933. 3*s*. 6*d*. net.)

THE author of this little monograph makes a bold attempt to rationalise cytological technique. This attempt involves avoidance of many well-known methods and strict limitation to a few methods which appear logical. The value of the book should therefore be assessed on what it contains rather than on what it omits, even if favourite methods be among the latter. The first chapter, which is introductory, deals with the structure of the living cell briefly and clearly. Much attention is paid to the effects of fixatives on the cells and particularly on the proteins of the cells, and experiments on the effects of various fixatives on protein solution *in vitro* are described in detail. Much space is also given to the chemistry of eight chief reagents used in fixation, *e.g.* ethyl alcohol, formaldehyde, acetic acid, picric acid, chromic acid, potassium dichromate, mercuric chloride, and osmium tetroxide. The properties of six fixing mixtures, namely the fluids of Carnoy, Bouin, Flemming, Altmann, Mann, and Da Fano are also dealt with in detail.

Altogether 66 pages are devoted to fixation, 6 to embedding, 36 to staining and 4 to mounting. The chapters on fixation, much the most valuable part of the book, contain a lot of information that will be found of use both to the experienced and the inexperienced technician, but they contain also much that in our view could well have been omitted. It would have been of far more value if some space had been devoted to expanding the section on embedding, which deals with the paraffin method exclusively, so as to include an account of the celloidin method and, if possible, of double embedding in celloidin and paraffin. The inclusion of a figure of a twig of the Balsam Fir (*Abies balsamea*) together with an account of its botanical peculiarities is irrelevant. Despite these faults most cytologists will find information in this book that is new to them and is both relevant and of great importance to their technique.

F. W. R. B.

Fighting the Insects. The Story of an Entomologist. By L. O. Howard. [Pp. xvii + 333.] (New York: The Macmillan Company; London: Macmillan & Co., Ltd., 1933. 12*s*. 6*d*. net.)

Much travelled and with fifty-odd years' official connection with entomology in the United States of America, one might almost add, in the world, L. O. Howard is equally well known for his entomology and his bonhomie. Already he has written *A History of Applied Entomology* (reviewed in January 1932) and *The Insect Menace* (reviewed in July 1932). Now he proceeds to tell the story of his life. The science of entomology may be said to have grown and developed parallel with the man. His life, crowded with opportunities readily seized, has therefore been full of exceptionally interesting experiences.

Beginning with several chapters which describe his earlier years, one gets a taste of what to expect—meetings with highly placed men in many walks of life. Chapter 5 for example is an account of the evolution of man's interest in the biological control of pests, which necessitated the co-operation of entomologists nearly all over the world and the author's journeys aimed successfully at making the liaisons required. Perhaps here lies the key to Howard's greatness. He faced wide questions with an open mind and, not satisfied with sending envoys to collect information, he went personally to investigate. Being endowed with the ability of creating friendships with whomsoever he met, he was successful in interesting entomologists of the world. More than this, he demonstrated in many spheres that entomologists are human beings.

Other chapters tell of mosquito investigations, silk culture in the U.S.A., the growth of the entomological service there, the development of the plant quarantine service and international congresses. In all these branches the author has taken no mean part. A busy man has always time to do additional service. This is true in Howard's case, as the American Association for the Advancement of Science has real cause to remember with gratitude his twenty-odd years' permanent secretaryship.

Notes concerning Presidents of the United States, a description of the famous Comos club of Washington and anecdotes concerning famous men bring the book to a conclusion with a mention of the fifth international congress of entomology in Paris in 1932.

"Surely the world knows a great deal more about our rivals, the insects, than it did when I was a youngster. I am thankful that fate has given me

a chance to see this progress, and to watch it from the inside, and to be one of the workers," so ends the first autobiography of an entomologist. A notable book concerning a notable man to whom, good luck!

H. F. B.

Plant Parasitic Nematodes and the Diseases they Cause. By T. Goodey, D.Sc. [Pp. xx + 306, with 136 figures.] (London: Methuen & Co., Ltd., 1933. 21s. net.)

Although there is an extensive literature on the "Eelworms" which attack plants, it is mainly scattered over numerous zoological, botanical and agricultural journals, and hitherto there has been no textbook devoted exclusively to these organisms. The aim of the present book has been to bring together in a convenient form all the most important information concerning them, and probably nobody in this country is so well qualified for the task as Dr. Goodey. For a number of years he has been occupied almost entirely with the study of this subject, and he is consequently in a position to give first-hand information concerning most of the species. In fact, a large part of the work is based on his own researches, and many of the excellent figures are taken from his own publications, or now appear for the first time.

In the first chapter the distribution and general structure of Nematodes are briefly but sufficiently described, and some useful methods of collecting, preparing and examining the smaller forms are given. In a section dealing with "measurements and proportions" the "formula" of the late Dr. N. A. Cobb for describing Nematodes is explained at some length. It seems rather a pity that the use of this tiresome method, which most systematic workers must have found a nuisance, should be perpetuated, but it is a relief to find that the author does not adopt it in those descriptions which are his own. The essence of Cobb's system is that all measurements except that of total length are given as percentages of that length. Much calculation is required to reduce them to actual measurements for comparison with actual specimens. Dr. Goodey apparently assumes that his readers know how to obtain accurate measurements of such small creatures, and does not tell us how we are to compare our measurements, when obtained, with the "formula."

In subsequent chapters the literature, morphology, life-history, biology and pathogenicity of the several species are discussed, and lists of host-plants and suggestions for control are given. Some thirty species, belonging to five genera, are thus dealt with, all of which are "obligate" parasites of the shoots or roots of plants. A chapter is then devoted to related forms, many of which are parasitic or semi-parasitic, but whose pathogenicity has not been established. A useful section of this chapter is given to the consideration of what the author terms "saprophytes." This seems a strange word to apply to animal organisms, but is here used for Nematodes occurring in decaying vegetable substances. It is very necessary to be able to distinguish these from genuinely parasitic forms. It might be suggested that "saprozoa" (for which there is at least German precedent) would be a better word in this connection. In a further section some account is given of "predators," or species which habitually or occasionally prey upon other Nematodes, and may thus help to keep the harmful kinds in check.

Lastly, there is a chapter on biological (or, as the author has it, in common with American writers, "biologic") races among the parasitic species. The existence of such races has received a good deal of attention in recent years,

and may have a considerable bearing upon the economic control of these forms in the future.

At the end of each chapter a good bibliography of the relevant literature is given, and at the end of the volume there is a general index. The latter might have been improved, perhaps, if specific names had been given separate entries. The book is well printed and of very convenient size. Dr. Goodey is to be congratulated on the production of a handbook which should prove very useful not only to specialists but also to economic biologists and others who may be called upon to investigate the causes of disease in plants.

H. A B.

MEDICINE

Human Embryology and Morphology. By Sir Arthur Keith. Fifth edition. [Pp. viii + 558, with 535 figures.] (London: Edward Arnold & Co., 1933. 32*s*. 6*d*. net.)

Users of the previous editions of Sir Arthur Keith's work have ever had reason to congratulate themselves at their good fortune in having presented to them in convenient and sympathetic form a clear account of the essential features of the vast accumulation of knowledge concerning the development and morphology of the human body. Now Sir Arthur has placed them still further in his debt with the appearance of the fifth edition of his book, and it is worth noticing as silent evidence of the soundness of its plan of construction that it has itself been capable of development and expansion by some 15 per cent. as regards both text and figures. For the medical student and human anatomist it will continue to be the only available work of its kind, and zoologists and biologists will find in it just that information which they require concerning man regarded as a highly developed vertebrate animal.

Medicine may be a profession and surgery an art, but anatomy, on which both are so dependent, is a science, and Sir Arthur Keith pursues the scientific method in the most profitable manner in appealing to morphology and to comparative and experimental embryology. There is no feature in the structure and development of the human body on to which light can fail to be thrown by such morphological and comparative treatment, whether for the benefit of the student, learning what is already known, or for that of the research worker, striving to extend the field of knowledge. All the way through his book, from the embryonic membranes to the structure of the foot, Sir Arthur brings to bear the weapon of morphology to force the human body to yield up its anatomical and embryological secrets.

With regard to the morphological problem of the relationship in which the embryological and anatomical departments of knowledge stand with regard to one another, the author insists that the facts of embryology only become intelligible and profitable for study when they are interpreted in the light of anatomy. In this he is doubtless right, but it is worth drawing attention to the philosophical interest of the problems involved. If it be really true that an embryonic stage can be fully comprehended and interpreted only in terms of anatomy, *i.e.* of the final stage and adult form which all embryos normally become, it would seem to follow that the fulfilment of an ontogeny involves some reading of the ultimate product into the stages preceding it. As a recent philosopher has said, while reminding us that he is but following Plato, "we must explain the undeveloped from the

developed, if we can explain it at all . . . In a sense indeed we cannot explain the undeveloped. Just because it is undeveloped it is incompletely what it is" [H. W. B. Joseph, *The Concept of Evolution*, Oxford, 1924].

But we would not have it thought that we are advocating a purposive teleological interpretation of development, nor do we for one moment suspect our author of such tendencies On the contrary, in addition to the general scientific aversion to such kinds of speculation, there is the increasing body of knowledge based on experimental embryology which goes to show that causal analysis can very profitably be applied to developing organisms, *i.e.* that subsequent stages (including the adult) are in a true sense the result of preceding stages. But these new discoveries also show that certain parts of developing embryos possess properties which, though known to involve physico-chemical processes, differ so profoundly from anything found in the inorganic realm that they can only be termed biological, and it is a matter, not of inference or speculation, but of observation and experiment that many of these properties result in [we must not say that they are "directed to"] the acquisition of the adult form. This also can happen when it should not, and Sir Arthur is careful to point out the significance of the fact that the amphibian "organiser" is the presumptive notochord, and that it is in the vicinity of the notochord that teratomata most commonly occur.

While we believe firmly that development is an act of epigenesis, *i.e.*, of successive causally conditioned responses to preceding situations and stimuli, we are apt to forget that while there are thousands of reasons why a frog's egg may fail to develop normally, there must be reasons why when it does develop normally, it becomes—a frog and nothing else. When we remember this fact, we find that we can give little by way of explanation except to say that it was a frog's egg and contained frog hereditary factors. The truth is that the old philosophical problem of unity in diversity, of the relation between potentiality and actuality, and of change, requires restating. And the facts which will have to be taken into account for the construction of such a synthesis are those of embryology and morphology, which in respect of man, form the subject of Sir Arthur Keith's book. While waiting for their synthesising philosopher, it is the scientist's duty to add to these facts, and the medical man's art to apply them.

There is another reason why embryological studies should command respect and attention, and that follows from the recognition of the fact that phylogenetic evolution is the result of successive slightly altered ontogenetic developments. We are now fortunately wise to the dangers attending the view that development is but a recapitulation of evolutionary history and directed by it.

A word should be added in praise of the figures illustrating the book. As in previous editions, all are done in line, and are models of clearness; they demonstrate once again the superiority of diagrams of this kind over photographs. We may perhaps be permitted to draw attention to a small error of reconstruction in Fig. 164 in which the upper jaw is represented as a visceral arch additional to instead of being part of the mandibular arch, and the eye is represented as lying ventral instead of dorsal to the trabecula cranii. Amphioxus has no pronephros (p. 412), but true ectodermal nephridia. If we may say so, we fear that it may be misleading to regard the notochord (p. 49) as an ingrowth of ectoderm, and we also regret that Gaskell's theory of the origin of vertebrates has not been allowed to lapse

into the quiet haven which there must assuredly be for all attractive fairy tales masquerading as scientific hypotheses. But these are small points, trivial compared with the excellent solid mass of the subject-matter, and we would not like our review of Sir Arthur Keith's book to end on any note other than that of the highest laudation.

G R. DE B.

The Tides of Life. By R G. HOSKINS, Ph.D., M.D. [Pp. xiv + 352, with illustrations] (London : Kegan Paul, Trench, Trübner & Co., Ltd , 1933. 15*s*. net)

A SUB-TITLE " The Endocrine Glands in Bodily Adjustment " amplifies the somewhat cryptic title at the same time that it explains the scope of this book, which makes a welcome addition to popular works on biological subjects for a number of which we have already to thank distinguished American scientists.

Investigations such as are here treated have a great popular appeal, for though the technique involved may be difficult and complicated, the results obtained are often of peculiar interest in themselves and are, moreover, concerned with matters familiar to the ordinary reader. Is an individual tall or short, intelligent or stupid, excitable or phlegmatic, stout or thin ? These are questions touching everyday experience, while the last, seems to-day to be of vital moment to a large section of the community.

This account of the properties and functions of the endocrine organs makes extremely good reading, it includes much of the most recent work in this field and the story of each gland is prefaced with a brief but valuable historical survey. The author, although he has exercised an expert critical faculty in the selection of material, happily has not omitted entertaining speculations as to the acceptance of which he may have reserves. A reported cure under treatment with one of these glands (together with sunshine and calcium !) of a person who flew into ungovernable rage at the slightest provocation leads him to remark that " morality has not yet, at any rate, been successfully reduced to chemistry." To another set of enthusiasts he says " to those who in the present state of our knowledge would glibly rewrite physiology and psychology in terms of pituitary function the timorousness of the proverbial angel is recommended ".

In describing the amazing activity of these structures it is indeed difficult not to fall into the language of hyperbole. When we realise for example that this same pituitary gland, which largely determines whether a person is to be a giant or a dwarf weighs only " about as much as an old-fashioned pill or ten small grains of wheat," or that from it a preparation has been made which will bring about its typical reaction when one grain of it is dissolved in a thousand tons of fluid it becomes easy to accept extreme statements. This gland also according to an investigator, who should certainly be able to amass a large fortune if his claim is substantiated, can be depended upon to cure baldness.

Many examples of the power of these glands to make or mar might be quoted. The book, indeed, is full of material which will give to those who retain a sense of the marvellous full scope for the exercise of this faculty.

But a warning must be given that though much has been discovered, much more investigation is necessary before disturbances in the functions

of these organs can be satisfactorily treated. How much has been done and also how much yet remains to be done will be gathered by the reader of this exceedingly interesting book.

W. C. CULLIS.

Stoke Park Monographs on Mental Deficiency and Other Problems of the Human Brain and Mind: No. 1, The Burden Memorial Volume. Edited by RICHARD J. A. BERRY, M.D., F.R.C.S. [Pp. xx + 249, with 89 plates and diagrams.] (London: Macmillan & Co., Ltd., 1933. 10*s*. 6*d*. net.)

THIS profusely illustrated volume consists of a collection of papers, for the most part reprinted, and deals with mental deficiency from many angles, but chiefly in respect of the relation of low mentality to defective cortical structure. Several of the papers are concerned with practical methods of diagnosis of mental deficiency, and are the fruit of researches in which physical measurements (particularly of brain capacity) as well as physical, psycho-physical and psychological tests have been applied to the subjects. They show that intelligence is correlated with brain-weight. Since, however, it is not possible to weigh the brains of living subjects, a further correlation is established between brain-weight and brain-capacity as calculated by head measurements. Particularly interesting are the chapters relating to cortical development; and the very original illustrations (by photographs of models invented by Dr. Berry) of the neural layers of the cortex as determined by Shaw Bolton and von Economo. It is shown that mental defect is connected with failure of development or degeneration of the supragranular layer; and the exceedingly complex and disputed subject of brain anatomy in relation to various types of mental defect is treated in as clear and simple language as could be desired. The book has a good index and a lengthy bibliography; and should, as one of the authors claims, bring "the varying views of experts within the compass of the general practitioner, who is in the best position to make that early diagnosis of onsetting mental disorder essential to any successful mental therapy."

F. A.

PHILOSOPHY AND HISTORY OF SCIENCE

Adventures of Ideas. By ALFRED NORTH WHITEHEAD, Sc.D., LL.D., F.R.S., F.B.A. [Pp. xii + 392.] (Cambridge University Press, 1933. 12*s*. 6*d*. net.)

THIS book, the author tells us in the preface, is supplementary to his *Science and the Modern World* and *Process and Reality*. In it he traces the adventure of ideas in promoting the gradual civilisation of mankind and also describes his own adventure in the realms of speculative philosophy in attempting to understand and explain this progress. The portion of human history upon which the author concentrates is that dealing with the transmission of civilisation from the Near East to Western Europe, and he sets out to demonstrate those factors in Western civilisation which are genuinely new in the history of culture. He enlarges on our debt to Christianity and the Greeks, and traces the rise of ideas on democracy and the humanitarian ideal.

In a chapter on Aspects of Freedom, Dr. Whitehead remarks that cultural

history can be considered from many aspects, but he does not mention the cyclic theory of Spengler which, one cannot help feeling, gives a much more profound account than that which he prefers to adopt, *viz.* considering the variations of emphasis between Individual Absoluteness and Individual Relativity. Nothing is more annoying to the reader than to start off by coining new and arbitrary terms beginning with capital letters, and ignoring entirely the monumental work of others on the same subject. Throughout the book and especially in the portion dealing with his own philosophy the author indulges in his habit of defining well-known words to have somewhat unusual meanings and this makes the book difficult reading.

Of the Greeks, of course, Whitehead maintains that he owes most to Plato who attempted to solve the problem of matter and change by the notion of Flux and Forms. For Whitehead the flux is actual and the idea of substance is only due to false inference from the observation of forms which endure for long periods. Although this philosophy has many advantages, especially from the biological point of view, it is undoubtedly one which is almost impossible to discuss in words. Words emphasise the substantial appearances of nature, or at least the recurrences, and are ill-adapted to discussion of the notion of flux.

And again one wonders whether we really understand what Plato meant by the Ideas, the Physical Elements, the Psyche, the Eros, the Harmony, the Mathematical Relations and the Receptacle. Whitehead holds that all philosophy is in fact an endeavour to obtain a coherent system out of some modification of these notions (p. 354) We have only to think, for instance, of the immense and insurmountable difference in the Greek view of the "Void" and our view of space, the seat of "tensions" and changing "forces," to realise that the words void and space are not interchangeable in any way. And when Whitehead himself admits that Plato's works are confusing and that sometimes he appears to mean one thing and sometimes another, one cannot help feeling very strongly that Spengler is right in maintaining that for one culture to understand the basic notions of another is quite impossible. The problems are the same, but the ideas are utterly incommensurable. Consequently when Whitehead attempts to illustrate his own philosophy by reference to that of Plato, the effect is to obscure rather than to clarify an already sufficiently difficult viewpoint.

The author admits that a culture will arrive at a culminating perfection beyond which there lies only staleness (characterised by the appearance of satire) but he seems to think that a quick transition is possible to a new epoch. For instance he suggests that "the misery of the Great War was sufficient for any change of epoch" (p. 359). According to Spengler, of course, this is quite impossible. It remains to be seen whether Dr. Whitehead's scholarly but somewhat obscure plea for Adventure and Foresight will be able to prevent The Decline of the West.

G. BURNISTON BROWN.

The Evidence of Our Senses. By A. W. P. WOLTERS, M.A. [Pp. viii + 88, with 3 illustrations.] (London: Methuen & Co., Ltd., 1933. 2*s*. 6*d*. net.)

MR. WOLTERS has contrived to compress into the space of six short chapters an exceedingly clear exposition of a most interesting subject. The book no doubt is intended for the ordinary reader; but it is none the less, besides

being clear, both scientific and exact. Taking the sense organs and nervous system for granted, the author deals with sensory perception from a purely psychological point of view, which the layman can readily assimilate and appreciate. He introduces his subject in a chapter which, largely because of the striking example he presents, drives home the problems of sense perception and hints at the difficulties in the way of their solution. He shows how we select and organise our present experiences under the influence of past ones, but always ourselves actively intervening in the process. He considers the limitations and illusions of sensory judgments, and the fallacies involved in remembering, with a view to setting forth the requirements of scientific observation—"scientific" here meaning nothing more than "accurate." And in a final chapter he throws together some practical suggestions which the reader will be tempted to extend and amplify for himself; for he will understand, as Mr. Wolters says, that "alike in the most elementary processes of perception and in the highest forms of enjoyment, we discover that what we can extract from life depends upon what we put into it." The book deserves a wide public

F. A.

The Making of Geography. By R. E. DICKINSON and O. J. R. HOWARTH. [Pp. viii + 264, with 30 figures and 5 plates.] (London: Oxford University Press, 1933. 8s 6d. net.)

THIS volume gives, in a very condensed but readable form, an account of the development of the science of Geography from the beginnings of civilisation. Its first illustration is a reproduction of a map of the world ascribed to c. 2700 B.C. But half of the book deals with developments during and after the nineteenth century.

The fourteen chapters of the first half treat of the gradual widening, except for the setback of the "dark ages" of early Christendom, of geographical knowledge and concepts. It is easy to let such a study become merely a record of exploration, and the authors are to be congratulated on the skill with which they have avoided this danger. The first of the five chapters which form the second half describes and evaluates the work of von Humbolt and Ritter, the founders of modern geography, both Germans though Humboldt did much of his work in Paris and his chief studies were in, and on, Central and South America. The rest deal respectively with Physical Geography, Human Geography, Biogeography, and the Regional Concept, which last is, as the authors say elsewhere (p. 142), "the heart of modern geography." We are too near to the development of this concept, which is to the science of geography what that of the conservation of energy was to physics, to make a fair estimate of the shares of the workers who have contributed to it. The names of P. Vidal de la Blache, in France, and of A. J. Herbertson, in Britain, stand out prominently among the founders; while important contributions to its application and elaboration have been made by many geographers of the present generation, in Germany, the U.S.A. and Italy as well as in the countries just named.

The book will be valuable to all who wish to gain a clear idea of the development of this particular branch of science. And the authors are to be congratulated on having produced a compact history of geography.

C. B. F.

The Horse and the Sword. By HAROLD PEAKE and HERBERT JOHN FLEURE. "The Corridors of Time VIII." [Pp. viii + 152, illustrated.] (Oxford: at the Clarendon Press, 1933. 5s. net.)

As the study of prehistory advances the inadequacy of the traditional divisions of prehistoric times into stone, bronze and iron ages to mark the crucial stages of development in culture becomes increasingly apparent. In the preface to this volume the authors point out that the transition from "Middle" to "Late" Bronze was "a period of crisis of far greater importance than the transition from the use of bronze to that of iron." "The Corridors of Time" series has shown a happy facility in crystallising in the titles of its parts the dominant characteristic of the period with which each has dealt. None has been happier than *The Horse and the Sword*. The appearance of the horse peoples armed with a new weapon, the sword, is at once the most striking feature and the informing element in the turmoil of the 400 years following on the fall of Knossos in 1400 B.C. with which it deals. The great empires of the Hittites in Asia Minor, of the Cassites of Mesopotamia, of Egypt and of Mycenæ, perish or fail and Troy is sacked; while the Achæans and Dorians descend on Greece, the Assyrians rise to power, an Aryan-speaking invasion appears in India and a new dynasty rises in China. It is a period which bristles with points upon which authorities have not yet reached agreement. Such controversial matters, it will be found, the authors have discussed clearly and judiciously with adequate consideration of views other than their own.

E. N. F.

Our Forefathers: The Gothonic Nations. Vol. II. By GUDMUND SCHÜTTE, Ph.D. [Pp. xvi + 482.] (Cambridge University Press, 1933. 30s. net.)

IN *Our Forefathers* Dr. Schutte has produced a work such as has long been desired by archæologists and historians, but that few would have had the courage or the learning to undertake. It is a survey of what is known of the ethnic composition and relations of the Germanic, or as Dr. Schütte would prefer, as the less ambiguous term, the Gothonic, nations in early Europe, more particularly at the moment when prehistory merges into history. He analyses the racial history and traces the racial movements which lie behind the distribution of peoples in modern Europe. Although he deals primarily with the Germanic group, that is to say with Gothic, German, Dutch, Anglo-Saxon, Frisian and Scandinavian peoples, he also covers, though in less detail, the other groups, Greek, Slavic and Italic, with which the Gothonic came into contact.

In the first volume, which was published in 1929, Dr. Schutte dealt with general questions affecting the Gothonic nations as a whole, and the position of the group as a part of the Indo-Germanic family. In the second volume, now published, the position of each member of the group is considered in turn. Here Dr. Schutte has had the assistance of experts in some of his sections. With characteristic modesty he holds that the chief merit of his own work lies in its method. It provides, he maintains, a framework to which the results of future work should conform in order to ensure that the material may be strictly comparable. In this framework he sets out and analyses the evidence from literary and historical references, place-names, archæology, linguistics, ethnology and tradition.

Dr. Schütte's method reveals many *lacunæ*, for which the lack of material and not the author is responsible. His book is a valuable contribution to archæological and historical studies, not least perhaps as a stimulus to future research.

E. N. F.

The Long Road—From Savagery to Civilization. By FAY-COOPER COLE. [Pp. xii + 100, with 6 figures.] (Baltimore: The Williams & Wilkins Company in co-operation with the Century of Progress Exposition, 1933; London: Baillière, Tindall & Cox. 5*s.* net.)

THIS little book gives an excellent survey of the early development of human culture for those who are not specialists in the subject. The first chapters deal with the discoveries of Pithecanthropus and Sinanthropus, the changes in type to Neanderthal and Cro-Magnon man and the industry and art pursued. Then follow accounts of the development of neolithic and metal age cultures—with a special section on the new stone age in America—until the rise of Greek and Roman civilisation. The central theme is the demonstration of progress in material achievement. The effect of continuity in invention is well maintained throughout, though one might perhaps point out that the archæological record of the earlier periods is in fact still very disconnected, and the impression of the unity and inter-relation of cultures here given is hence somewhat over-stressed. The book is written in an interesting manner, and without superfluity of technical vocabulary to alarm the general reader.

RAYMOND FIRTH.

The Progress of Man: a Short Survey of his Evolution, his Customs and his Works. By A. M. HOCART, M.A. [Pp. xvi + 316.] (London: Methuen & Co., Ltd., 1933. 7*s.* 6*d.* net.)

IN the study of man at the present moment not only is there a danger that the anthropologist may lose sight of the wood because of the trees, but each group of investigators shows an increasing tendency to see only one kind of tree. The fault lies not so much in over-specialisation—specialisation is a necessity of profitable research—as in a failure to keep in view the unity of anthropological studies as leading ultimately to a knowledge of the bodily and spiritual nature of man as revealed in his past and in his present. There is a failure to grasp the need of synthetic study which, unless speedily remedied, will relegate the science to the sphere of the purely academic, except in so far as it feeds the popular appetite for the sensational—a weakness of present methods which some authropologists, at least, justly condemn. However much the outlook of the sociological or functional school of anthropology may be criticised as being too narrow, it has at least the merit that it keeps in touch with the realities of the material under investigation. Its methods and results are applicable to practical everyday affairs among primitive peoples.

For an older generation the study of man on broad and comprehensive lines was a simpler problem. Now the student is overwhelmed by the mass of facts that has accumulated since that day. In *The Progress of Man* Mr. Hocart sets out to provide a framework into which these facts may be fitted. His attempt is more than welcome, especially as he boldly casts down the barriers between prehistory and history, between "ancient" man

and the modern savage. He links up the culture of the backward races with our own civilisation, "uses savages and antiquity merely to throw light on ourselves," to quote his own words.

Mr. Hocart's attitude towards his subject-matter may be indicated by his understanding of the much-abused term "evolution." In dealing with technology, for example, and what is called "material" culture, he points out that the subject of investigation, from his standpoint, is not the material product, or the various stages of its development, but the process of evolution in man's mind that is revealed thereby. This method he applies through the whole gamut of man's activities, illustrating it with a wealth of detail, which is handled with a mastery possible only to one who has the author's first-hand knowledge of backward peoples and their attitude towards the problems of everyday life.

Controversial matters inevitably occupy no inconsiderable place in the argument and are forcefully handled. No apology is necessary for passing these over and confining this notice to the more general question of principle. Herein lies the most important contribution in this book to the advancement of anthropological studies E. N. F.

Sexual Regulations and Human Behaviour. By J. D. Unwin, M.C., Ph.D. [Pp. xv + 108.] (London: Williams & Norgate, Ltd., 1933. 7*s*. 6*d*. net.)

The thesis of this volume, which is merely a summary of the argument of a larger work in preparation, is briefly that culture depends on continence—that is, the mental energy of a society stands in direct relation to the amount of chastity observed by its members before marriage. As a corollary it is claimed that if we know what the sex regulations of a community are we can accurately predict the pattern of its culture.

This view is apparently based on a survey of the customs of eighty tribes or so. Though novel as applied to the whole field of culture, it seems to have much in common with the idea of the savage who abstains from sexual intercourse for some time before engaging in critical pursuits lest his vigour be impaired. In this respect, at least, Mr. Unwin's thesis may be regarded as anthropological. It is possible that the adduction of the full body of his evidence will later compel conviction, but meanwhile the outlook is not too promising. A most important aspect of the argument is the division of all human societies into rationalistic, deistic, manistic and zoistic—a few civilised societies alone comprising the first category. Societies are deistic when they erect temples (which by definition must be buildings large enough for a man to stand upright inside), manistic when they do not do this but pay some post-funeral attention to their dead, and zoistic when they do neither. The Polynesian scholar will note with interest that by this arbitrary distinction the Tongans and Samoans are classed as deistic, whereas the Maori, whose system of deities was if anything more complex and highly developed still, are placed—under the "Indisputable" section of evidence—merely in the manistic category. Three generations are taken for continence (or the reverse) to work itself out. We are given then as a "secondary law": Any society in which pre-nuptial sexual freedom has been permitted for at least three generations will be in the zoistic cultural condition.

In this vein the book proceeds. Raymond Firth.

Functional Affinities of Man, Monkeys and Apes. By S. Zuckerman, M.A., D.Sc., M.R.C.S., Research Associate, Yale University. [Pp. xviii + 203, with 24 plates and 4 figures.] (London: Kegan Paul, Trench, Trübner & Co., Ltd., 1933. 10*s.* 6*d.* net.)

In the words of the author, the purpose of this study is to give "a taxonomic and phylogenetic survey of the findings of diverse experimental investigations of lemurs, monkeys and man." In a two-fold sense, Dr. Zuckerman enters upon a new field. The results of experimental biology have not hitherto been brought to bear on the problems of the systematist—this applies particularly to man—and the systematist has tended to confine himself to morphological characters—again a tendency especially to be noted in the study of the descent and racial classification of man. In fact, while there are innumerable measurements of the anatomical characters of the various races, the study of function as a measure of racial differentiation has been almost entirely neglected. The attention now being given to the blood groups in anthropological studies may mark a turn in the tide. Should this prove to be the case, Dr. Zuckerman's work will receive due credit as a pioneer study.

A wide and diverse field is covered in this volume. It ranges from intelligence tests and behaviour in the primates to the function of the reproductive system and to disease and parasites. The chapter of, perhaps, greatest interest deals with the bearing of the results of experimental study of the brain, even though it leads to no very definite conclusion. In this, however, it is not singular, and chapter after chapter conveys a very definite impression of the need for a great deal of further research before these "characters" can be used as a basis of classification with the assurance at present conceded to morphological characters.

On the other hand, the conclusions, tentative as they often are, are invariably stimulating, and sometimes surprising. Take, for example, the survey of work on the blood groups. Dr. Zuckerman finds that the blood groups of the anthropoids are the same as in man, but occur in no other animal: yet the blood groups appear to have evolved differently in the African and the Eastern apes. Of the possible explanations, one is that if man acquired his blood groups from an ape or an ape-like precursor, it would have to be assumed that many human beings have greater affinity with the existing Asiatic anthropoids than with those of Africa. This somewhat surprising conclusion agrees with an hypothesis put forward some years ago on purely morphological grounds which failed to secure support.

Dr. Zuckerman's book will appeal strongly to the anthropologist who feels the weaknesses of present methods in taxonomy and phylogeny. He will welcome the extension to "characters" in a new field.

E. N. F.

MISCELLANEOUS

Maps and Survey. By Arthur R. Hinks, C.B.E., M.A., F.R.S. Third Edition. [Pp. xii + 283, with 32 figures and 28 plates.] (Cambridge: at the University Press, 1933. 12*s.* 6*d.* net.)

The third edition of this book, which has proved so useful to students of Geography in the past, is greatly altered from the early ones. In a brief review, it is possible to mention only a few of the more valuable additions.

The first chapter, giving a brief history of early maps, introduces the subject in a clear and interesting way, leading up to a careful analysis of the modern map, full of keen criticism and useful hints, particularly on recent designs in lettering.

Then follow chapters of description of British and foreign maps, as in the earlier editions, but greatly extended and brought up to date. An excellent but brief chapter on atlases points out the need for greater originality and enterprise in atlas production, particularly in the English language.

The chapters on various types of surveys are also expanded from the originals where new methods have assumed importance, but they keep the same general purpose, introducing the reader to the methods in use without confusing him with the detailed processes required in their practice

The chapter on photographic surveying departs somewhat from this principle in so far as it introduces the slight amount of mathematical theory necessary to explain the problem, but it succeeds in giving in a short space a very lucid account of the difficulties and of the methods now in use.

The book is well illustrated, many of the diagrams and blocks being new.

F. D.

Riddles of the Gobi Desert. By Sven Hedin. [Pp. x + 382, with 24 plates and a map.] (London: George Routledge & Sons, Ltd., 1933. 5*s*. net.)

While all of us would wish to lay tribute to the work and enthusiasm of Dr. Sven Hedin, this book, which is a sequel to his *Across the Gobi Desert*, is a disappointment. There are many bits of it which are vivid and extremely interesting; other parts are of importance historically, especially, for instance, the account of Governor-General Yang. On the other hand, it is of no particular moment to hear of visits to the United States by the leader of the expedition in quest of a medical adviser, nor to note that a particular person showed him round a particular museum. The translation has been well done, though for English readers degrees of temperature should have been given in Fahrenheit. The map is taken from the German edition, but though the legend has been Englished, an oblong has been left in the middle labelled as the "Gebiet der Sonderkarte," though no Sonderkarte survives. Throughout the book there is little sympathy for the people of Mongolia; one of Dr. Hedin's young men boasts that he knows nothing of the languages, and makes no attempt to learn them. Nor can one sympathise with the way in which their religion is treated. The present writer has seen a service in a temple in Mongolia conducted with much unseemliness on the part of the younger lamas, but that was the affair of the Mongols. But the attempts to buy temple yurts by a stranger with gold is likely to do much harm should it become understood in Asia, that country whose temple doors always stand open to any one on a true religious quest.

In many parts of the book, however, we get vividly described the glamour and charms of the Gobi, and of the free, precarious life of the Mongols, a manner of existence which has descended to us as a survival from many centuries. Dr. Hörner's diary of his work on Lop Nor is of especial interest here, but it should be said in justice to them that most of the diaries of the young commanders of various branch expeditions, when they can for the moment remember that it is their scientific work, not their patriotic

emotions, that are interesting, give extremely good accounts of their geographic surroundings.

After the book is finished one is still left wondering exactly what it is all about, and one misses the clear simple summaries of their work which have been given by either the members or the headquarters of that other expedition to Gobi, conducted by the American Museum of Natural History.

L. H. DUDLEY BUXTON.

Biology in Education. Edited by J. G. CROWTHER. [Pp. x + 204.] (London: William Heinemann, Ltd., 1933. 7*s*. 6*d*. net.)

IN 1932 the British Social Hygiene Council convened a conference on the place of biology in education. It did so because its work during the previous decade had revealed that health education can only be effectively carried out when there is a background of biological knowledge. And this background was almost completely lacking. The volume under review is a result of this conference. It contains a summary of the proceedings well edited by Mr. J. G. Crowther and is divided into sections dealing with (1) the national and imperial need for a biological outlook, (2) biology in the public, secondary and preparatory schools, (3) biology in the elementary, central and technical schools, (4) the place of biology in public education, and (5) biology in the training colleges.

The entry of biology into the school curriculum represents probaby the most important recent development in education. The extent to which schools are teaching biology is revealed by the ever-increasing numbers of honours students in zoology and botany, notably in the former, and by the numbers of teachers who attend vacation courses in biology. The advocates of the teaching of biology are now knocking at an open door and though some may be a little dissatisfied at the rate at which such teaching is increasing this is due more to lack of trained teachers than to any other factor. Several points of particular interest emerge from the discussions summarised in the volume under review. One is the importance of the teaching of elementary biology, or nature study, in the elementary schools. The flow from the villages to the towns has been arrested as industry has waned and agriculture increased in importance. There is no subject which might more suitably form the background of the education of future farmers and farm labourers than biology, particularly in these days of intensive horticulture which depends so largely on a detailed knowledge of fertilisers and of insect and fungus pests.

In higher education particular stress is laid on the "cultural" value of biology. Sir William Hardy and Professor Douglas Laurie in their communications to the Conference give the most adequate expression to this. The former points out that the mentality of the modern mind has "never been exceeded in its capacity for slavery to suggestion and catch-phrases" and considers that there is nothing more urgently needed than the teaching of natural science which exalts reason at the expense of emotion. Professor Laurie considers that "many of the old sanctions for conduct have weakened or have gone and the furnishing of new sanctions is falling in no small part to the lot of Biology."

This book can be strongly recommended to all who are interested in education.

C. M. Y.

BOOKS RECEIVED

(Publishers are requested to notify prices)

Algebraic Functions. By Gilbert Ames Bliss, Professor of Mathematics, the University of Chicago. American Mathematical Society Colloquium Publications. Vol XVI. New York: American Mathematical Society, 1933. (Pp. x + 218, with 42 figures.)

Bulletin of the National Research Council. No. 92. Numerical Integration of Differential Equations Report of Committee on Numerical Integration. Washington, D.C.: The National Research Council of The National Academy of Sciences, 1933. (Pp 108.) $1.00

Principles of Geometry. By H F Baker, Sc D., LL.D., F.R.S., Lowndean Professor, and Fellow of St. John's College, in the University. Vol. V: Analytical Principles of the Theory of Curves Cambridge: at the University Press, 1933. (Pp. x + 247.) 15*s*. net.

Principles of Geometry. Vol. VI: Introduction to the Theory of Algebraic Surfaces and Higher Loci By H. F. Baker, Sc.D., LL.D., F.R.S., Lowndean Professor, and Fellow of St John's College, in the University. Cambridge: at the University Press, 1933. (Pp. x + 308.) 17*s*. 6*d*. net.

Statics. A Textbook for the use of the Higher Divisions in Schools and for First Year Students at the Universities By A. S. Ramsey, M.A., President of Magdalene College, Cambridge Cambridge: at the University Press, 1934. (Pp. xii + 296.) 10*s* 6*d*. net

Elementary Calculus: Vol. II By C. V. Durell, M A., Senior Mathematical Master, Winchester College, and A. Robson, M.A., Senior Mathematical Master, Marlborough College. London: G. Bell & Sons, Ltd., 1934 (Pp. xii + 308, with 62 figures.) 7*s*. 6*d*. with appendix. 6*s*. 6*d*. without appendix.

The Universe Around Us. By Sir James Jeans, M.A., D.Sc., Sc.D., LL.D., F.R.S. Third edition. Cambridge. at the University Press, 1933. (Pp. x + 380, with 30 plates and 23 figures.) 12*s*. 6*d*. net.

Bulletin of the National Research Council. No. 90. Physics of the Earth —VI. Seismology. By the Sudsidiary Committee on Seismology. Washington, D.C.: The National Research Council of The National Academy of Sciences, 1933. (Pp. viii + 223, with 28 figures.) $2.00.

Introduction to Theoretical Physics. By John C. Slater, Ph.D., Professor of Physics, and Nathaniel H. Frank, Sc.D., Assistant Professor of Physics, Massachusetts Institute of Technology. International Series in Physics. New York and London: McGraw-Hill Book Co., Inc., 1933. (Pp. xx + 576, with 83 figures.) 30*s*. net.

The Crystalline State. Edited by Sir W. H. Bragg, O.M., K.B.E., D.Sc., F.R.S., and W. L. Bragg, D.Sc., F.R.S. Vol. I: A General Survey. By W. L. Bragg. London: G. Bell & Sons, Ltd., 1933. (Pp. xiv + 352, with 187 figures, including 32 plates.) 26*s*. net.

Experimental Elasticity. A Manual for the Laboratory. By G. F. C. Searle, Sc.D., F.R.S., University Lecturer in Experimental Physics and Demonstrator in Experimental Physics at the Cavendish Laboratory. Second edition Cambridge at the University Press, 1933. (Pp. xvi + 189, with 63 figures.) 7*s* 6*d*. net.

A Textbook of Physics Vol. IV · Optics. By E. Grimsehl. Edited by R. Tomaschek, D.Phil., Professor of Physics, the University of Marburg. Authorised Translation from the Seventh German Edition by Winifred M. Deans, M.A. (Cantab.), B.Sc. (Aberd.). London and Glasgow: Blackie & Son, Ltd., 1933 (Pp. xiv + 301, with 353 figures, including 16 plates, and 1 coloured plate.) 15*s*. net.

Colour Science. A Handbook for Advanced Students in Schools, Colleges, and the various Arts, Crafts, and Industries depending on the use of Colour. By Wilhelm Ostwald. Authorised Translation by J. Scott Taylor, M.A., Scientific Director, Winsor & Newton, Ltd. Part II: Applied Colour Science. London: Winsor & Newton, Ltd., 1933. (Pp. xii + 173, with frontispiece, 18 figures and 2 plates.) 10*s*. 6*d*.

Electrons at Work. A simple and general treatise on electronic devices, their circuits, and industrial uses. By Charles R. Underhill. New York and London: McGraw-Hill Book Co., Inc., 1933. (Pp. xii + 354, with frontispiece and 220 figures.) 18*s*. net.

The Electromagnetic Field. By H. F. Biggs, M.A., M.Sc., Demonstrator in Physics, The Electrical Laboratory, Oxford. Oxford: at the Clarendon Press. London: Humphrey Milford, 1934. (Pp. viii + 158, with 38 figures.) 10*s*. 6*d*. net.

Electromagnetic Waves. By F. W. G. White, M.Sc., Ph.D., Assistant Lecturer in Physics, King's College, London. Methuen's Monographs on Physical Subjects. London: Methuen & Co., Ltd., 1934. (Pp. viii + 108, with 26 figures.) 3*s*. net.

Bulletin of the National Research Council. No. 93. Systems of Electrical and Magnetic Units. Papers presented before the American Section, International Union of Pure and Applied Physics, Chicago, June 24, 1933. Washington, D.C.: The National Research Council of The National Academy of Sciences, 1933. (Pp. vi + 112, with 4 figures and 6 tables.) $1.00.

Müller-Pouillets Lehrbuch der Physik. Eleventh edition. Vol. IV—Part 4. Elektrische Eigenschaften der Metalle und Elektrolyte; magnetische Eigenschaften der Materie. Edited by Arnold Eucken, Göttingen. Braunschweig: Friedr. Vieweg & Sohn Akt.-Ges., 1934. (Pp. xx + 906, with 400 figures.) RM.62—paper covers, RM.66—bound.

Physical Constants. Selected for Students. By W. H. J. Childs, B.Sc., Ph.D., The Davy-Faraday Research Laboratory, The Royal Institution. Methuen's Monographs on Physical Subjects. London: Methuen & Co., Ltd., 1934. (Pp viii + 77, with 7 monograms.) 2*s*. 6*d*. net.

Progressive Problems in Physics. Completely revised. By Fred R. Miller, Head of the Department of Science, The English High School, Boston. Boston: D. C. Heath & Co. London: George G. Harrap & Co., Ltd., 1933. (Pp. viii + 225, with 66 figures.) 3*s*. 6*d*.

Industrial Heat Transfer. By Alfred Schack, Dr.-Ing., Direktor, Rekuperator G.m.b.H., Dusseldorf. Translated by Hans Goldschmidt, Dr.-Ing., and Everett P. Partridge, Ph.D., Supervising Engineer, Nonmetallic Minerals Experiment Station, United States Bureau of Mines. New York: John Wiley & Sons, Inc London: Chapman & Hall, Ltd., 1933. (Pp. xxiii + 371, with 40 figures.) 31*s*. net.

A Textbook of Inorganic Chemistry By Dr. Fritz Ephraim, Professor of Chemistry in the University of Berne. English edition by P. C. L. Thorne, M.A. (Cantab.), M.Sc., Ph.D. (Lond.), sometime Lecturer in Chemistry at the Sir John Cass Technical Institute, London, and at Woolwich Polytechnic. Second edition London: Gurney & Jackson, 1934 (Pp. xii + 873, with 85 figures.) 28*s* net.

The Principles of Metallurgy. By Donald M. Liddell, and Gilbert E. Doan, Ch.E., Ph D. (Berlin), Associate Professor of Physical Metallurgy, Lehigh University. New York and London: McGraw-Hill Book Co., Inc., 1933. (Pp. viii + 626, with 324 figures) 30*s*. net.

Technique of Modern Welding. By Professor P Bardtke, Oberregierungsrat and Works Manager of the State Railway Repair Workshops, Wittenberge; Fellow of the Technical High School, Hanover. Authorised Translation from the second German edition, with additions and revisions by Professor Bardtke, by Harold Kenney, B.A. London and Glasgow: Blackie & Son, Ltd., 1933. (Pp. xii + 299, with 315 figures) 15*s*. net.

Outlines of Organic Chemistry. By F. J. Moore, Ph.D., Late Professor of Organic Chemistry in the Massachusetts Institute of Technology. Revised by William T. Hall, Associate Professor of Analytical Chemistry in the Massachusetts Institute of Technology. Fourth edition. New York: John Wiley & Sons, Inc. London: Chapman & Hall, Ltd., 1933. (Pp. xiv + 338, with frontispiece and 15 figures.) 16*s*. 6*d*. net

Asymmetric Synthesis and Asymmetric Induction. By Patrick D. Ritchie, B.Sc., Ph.D. St. Andrews University Publication No. XXXVI. London: Oxford University Press, 1933. (Pp. x + 155, with 3 figures.) 7*s*. 6*d*. net.

An Introduction to the Biochemistry of Nitrogen Conservation. By Gilbert J. Fowler, D.Sc., F.I.C., Professor (retired) of Biochemistry in the Indian Institute of Science, Bangalore. London: Edward Arnold & Co., 1934. (Pp. viii + 280, with 6 plates, 13 figures and a folding diagram.) 12*s*. 6*d*. net.

Fundamentals of Biochemistry in relation to Human Physiology. By T. R. Parsons, B.Sc. (Lond.), M.A. (Cantab.), Sidney Sussex College, Cambridge. Fourth edition. Cambridge: W. Heffer & Sons, Ltd., 1933. (Pp. xii + 435, with 26 figures, including 1 plate.) 10*s*. 6*d*. net.

Elementary Qualitative Analysis. By F. M. Brewer, B.Sc., M.A. (Oxon.), Ph.D. (Cornell), University Demonstrator in Chemistry, Oxford. Oxford: at the Clarendon Press. London: Humphrey Milford, 1933. (Pp. viii + 228.) 6*s*. net.

Chemical Calculations. Their Theory and Practice. By A. King, M.Sc., A.R.C.S., D.I.C., and J. S. Anderson, Ph.D., A.R.C.S., D.I.C., both of the Chemistry Department, Imperial College of Science and Technology. London: Thomas Murby & Co. New York: D. van Nostrand Co., Inc., 1933. (Pp. x + 181.) 4*s*. 6*d*. net.

A Course of Chemistry for Schools. By W. Taylor, B.Sc., Senior Chemistry Master, County School for Boys, Beckenham. London: George G Harrap & Co., Ltd., 1933 (Pp. 513, with 141 figures.) Complete 6*s*.; Part I, 3*s*. 6*d*.; Part II, 3*s* 6*d*.

Thin-Section Mineralogy. By Austin F. Rogers, Ph.D., Professor of Mineralogy and Petrography, Stanford University, and Paul F. Kerr, Ph.D., Associate Professor of Mineralogy, Columbia University. New York and London: McGraw-Hill Book Co., Inc, 1933. (Pp. xiv + 311, with 261 figures.) 18*s*. net.

The Determination of the Feldspars in Thin Section. By Dr. Karl Chudoba, University of Bonn. Translated by W. Q. Kennedy, D.Sc., H.M. Geological Survey. London: Thomas Murby & Co. New York: D. van Nostrand Co., 1933. (Pp. xii + 62, with 50 figures.) Cloth, 6*s*. 6*d*. net; paper, 4*s*. 6*d*. net.

Virus Diseases of Plants. By John Grainger, Ph.D., B.Sc. London: Oxford University Press, 1934 (Pp. viii + 104, with 6 plates and 5 figures.) 6*s*. net.

Pflanzenthermodynamik. By Kurt Stern. Berlin: Julius Springer, 1933. (Pp. xii + 412, with 20 figures.) RM.32—paper covers, RM.33.20—bound.

Researches on Fungi. Vol. V. By A. H. Reginald Buller, D.Sc., Ph.D., F.R.S., Professor of Botany at the University of Manitoba. London, New York, Toronto: Longmans, Green & Co., 1933. (Pp. xvi + 416, with 174 figures.) 25*s*. net.

A Manual of the Timbers of the World. Their Characteristics and Uses. By Alexander L. Howard. Second edition. London: Macmillan & Co., Ltd., 1934. (Pp. xxiv + 672, with 91 illustrations.) 36*s*. net.

Plants and Human Economics. By Ronald Good, M.A. (Cantab.), Head of the Department of Botany, University College, Hull. Cambridge: at the University Press, 1933. (Pp. xii + 202, with 8 maps.) 5*s*.

Aids to Botany. By H. J. Bonham, B.Sc., Biology Master, Crypt School, Gloucester. London: Baillière, Tindall & Cox, 1934. (Pp. viii + 221, with 47 figures.) 3*s*. 6*d*.

Handbook of Frogs and Toads. The Frogs and Toads of the United States and Canada. By Anna Allen Wright and Albert Hazen Wright, Professor of Zoology, Cornell University. Handbooks of American Natural History, Vol. I. Ithaca, New York: The Comstock Publishing Co., Inc., 1933. (Pp. xii + 231, with 82 plates and 7 figures.) $2.50.

An Economic Entomology of the West Indies. By George N. Wolcott. San Juan: The Entomological Society of Puerto Rico, 1933. (Pp. xviii + 688, with 111 figures.) $2.00, post paid.

The Ecology of Animals. By Charles Elton, M.A., Director, Bureau of Animal Population, Department of Zoology and Comparative Anatomy,

Oxford University. Methuen's Monographs on Biological Subjects. London: Methuen & Co., Ltd., 1933. (Pp. x + 97.) 3*s*. 6*d*. net.

A German Reader for Biology Students. Passages from recent German scientific publications. Selected and arranged by H. G. Fiedler, M.A., Ph.D., Taylor Professor of German Language and Literature in the University of Oxford, and G. R. de Beer, M.A., D.Sc., Jenkinson Lecturer in Embryology in the University of Oxford. With a Vocabulary by Herma E. Fiedler, M.A. London. Oxford University Press, 1933 (Pp. viii + 92.) 5*s*

A New Physiological Psychology. By W. Burridge, D.M., M.A. (Oxon.), Professor of Physiology, Lucknow University. With a Foreword by Sir Leonard Hill, M.B., LL.D., F.R.S. London: Edward Arnold & Co., 1933. (Pp. viii + 158, with 6 figures.) 7*s*. 6*d* net.

The Spread of Tumours in the Human Body. By Rupert A. Willis, M.D., B.S., D.Sc., Melbourne, Pathologist to the Alfred Hospital and to the Austin Hospital for Chronic Diseases, Melbourne. Monographs of the Baker Institute of Medical Research, No. 2. London: J. & A. Churchill, 1934. (Pp. x + 540, with 103 illustrations.) 25*s*. net.

The Cancer Problem and its Solution. By Hastings Gilford, F.R.C.S. London: H. K. Lewis & Co., Ltd., 1934. (Pp. iv + 60.) Cloth 2*s* 6*d* net. Paper 1*s*. 6*d*. net.

The Organism of the Mind. An Introduction to Analytical Psychotherapy. By Gustav Richard Heyer, M.D. Translated by Eden and Cedar Paul. London: Kegan Paul, Trench, Trübner & Co., Ltd., 1933. (Pp. xiv + 271, with 37 illustrations.) 15*s*. net.

The Brain and its Mechanism. By Sir Charles Sherrington, O.M., G.B.E., F.R.S., Waynflete Professor of Physiology in the University of Oxford, Being the Rede Lecture delivered before the University of Cambridge, 5th December 1933. Cambridge: at the University Press, 1933 (Pp. 35.) 1*s*. 6*d*. net.

Constitution and Health. By Raymond Pearl, Professor of Biology in The Johns Hopkins University, Baltimore. London: Kegan Paul, Trench, Trübner & Co., Ltd., 1933. (Pp. 97, with 5 plates and 4 figures.) 2*s*. 6*d*. net.

The Construction of Man's Family Tree. By Sir Arthur Keith, M.D., F.R.S. The Forum Series, No. 18. London: Watts & Co., 1934. (Pp. vi + 54, with 10 figures.) 1*s*. cloth. 7*d*. paper.

Science, Religion and Man. By The Reverend William John James Cornelius, M.A., B.D., D.Litt., D.Sc., A.K.C., Vicar of All Saints' Church, North Peckham, London, Commissary to the Lord Bishop of Fredericton, Canada. London: Williams & Norgate, Ltd., 1934. (Pp. 387, with 1 plate.) 15*s*. net.

Logic in Practice. By L. Susan Stebbing, D.Lit., M.A., Professor of Philosophy in the University of London. Methuen's Monographs on Philosophy and Psychology. London: Methuen & Co., Ltd., 1934. (Pp. x + 113.) 2*s*. 6*d*. net.

Origines et Formes de la Pensée. By F. Carrel. Paris: Vigot Frères, 1934. (Pp. 115.)

The Romance of Research. By L. V. Redman, Vice-President and Director of Research, and A. V. H. Mory, Associate Director of Research, Bakelite Corporation. A Century of Progress Series. Baltimore: The Williams & Wilkins Co., in co-operation with The Century of Progress Exposition, 1933. London: Baillière, Tindall & Cox. (Pp. x + 150, with 6 figures.) 5*s*. net.

On a New Chemical Theory and Researches on Salicylic Acid. Papers by Archibald Scott Couper (1858). Alembic Club Reprints—No. 21. Edinburgh: Oliver & Boyd, for the Alembic Club. London: Gurney & Jackson, 1933. (Pp. 45.) 2*s*. 6*d*.

Richard Trevithick. The Engineer and the Man. By H. W. Dickinson and Arthur Titley. Trevithick Centenary Commemoration Memorial Volume. Cambridge: at the University Press, 1934. (Pp. xviii + 290, with 18 plates and 41 figures.) 10*s*. 6*d*. net.

A Bibliography of Sir James George Frazer, O.M. Compiled by Theodore Besterman, with a Note by Sir J. G. Frazer. London: Macmillan & Co., Ltd., 1934. (Pp. xviii + 100, with portraits and facsimiles.) 12*s*. 6*d*. net.

A Record of the Scientific Work of Sir James Dewar. London: printed for private circulation at the Chiswick Press, 1933. (Pp. 68.) 5*s*.

Darwin. By R. W. G. Hingston. Great Lives Series. London: Gerald Duckworth & Co., Ltd., 1934. (Pp. 144.) 2*s*. net.

Pagan Survivals in Mohammedan Civilisation. By Edward Westermarck, Ph.D., Hon. LL.D. (Glasgow and Aberdeen), late Martin White Professor of Sociology in the University of London. London: Macmillan & Co., Ltd., 1933. (Pp. viii + 190, with 74 figures.) 8*s*. 6*d*. net.

Inland Waters of Africa. The result of two expeditions to the Great Lakes of Kenya and Uganda, with accounts of their biology, native tribes and development. By S. and E. B. Worthington. London: Macmillan & Co., Ltd., 1933. (Pp. xx + 259, with 40 plates, 13 figures and a map.) 15*s*. net.

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Bulletin of the National Research Council. No. 91. Industrial Research Laboratories of the United States. Fifth edition. Compiled by Clarence J. West and Callie Hull. Washington, D.C.: The National Research Council of The National Academy of Sciences, 1933. (Pp. 223.) $2.00.

Science and the Police Officer. By Henry T. F. Rhodes, of the International Academy of Criminology. London: The Police Chronicle, 1934. (Pp. xvi + 180.) 5*s*. net.

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